Co-funded by the
Erasmus+ Programme
of the European Union

The impact of Public Space's Temporary Interventions in Outdoor Thermal Comfort and Microclimate

Analysis of Lahti's Market Square during Spring

Milagros Guadalupe Saloma Pacheco

A thesis submitted for the Joint programme of

Master in Urban Climate & Sustainability

August, 2021

Author
Saloma Pacheco, Milagros Guadalupe

Publication type
Thesis

Completion year
2021

Number of pages: 119

Supervisor I

Prof./Dr. Eeva Arrevaara

Supervisor II

Prof./Dr. Denise Duarte

The impact of Public Space's Temporary Interventions in Outdoor Thermal Comfort and Microclimate Analysis of Lahti's Market Square during Spring

Degree: Master in Urban Climate & Sustainability

Temporary interventions in the public spaces are common in the urban landscape (e.g. street markets, parklets or sun sails); however, few studies have analysed their effects on microclimate and outdoor thermal comfort, especially in the Nordic countries. Outdoor thermal comfort has a physiological and psychological aspect; therefore, it has a site-specific understanding. Moreover, Climate Sensitive Urban Design (CSUD) searches for pleasant spaces by mitigating urbanization effects and weather. The study's relevance is to define effective and immediate low-cost solutions that cope with the rapid effects of climate change and users' desires and create more liveable places using temporary interventions.

This study reviews and compares the thermal comfort and microclimatic implications of existing temporary elements in Lahti's Market Square (Finland) during two critical spring days (warm and cold) in recent years to develop a list of strategies that bring an overall improvement of the site. Three scenarios were analysed on each day with ENVImet to analyse Potential air temperature (T_{Air}), Mean Radiant Temperature (MRT) and Physiological Equivalent Temperature (PET). The scenarios considered: no interventions in the plaza as the base case (S1), the usual Daily Market (S2) and the Monthly Market (S3) based on field surveys made in May 2021. Field measurement validated the performance of ENVI-met. In parallel, an online survey revealed users' behaviour, preferences and desires for the plaza, and two interviews presented the logistics and plans of the site.

Results exposed that existing temporary elements effects had a major impact on MRT and PET than T_{Air}. Additionally, they created more comfortable environments at specific hours (warming effect in the cold day and cooling effect in the warm day), especially for creating various microclimates. However, effects were more substantial on the warm day. Also, the higher the percentage of occupancy of the plaza was, the more significant effects they had. When comparing the existing vegetation with the temporary elements, the first ones had better results on the warm day because of evapotranspiration. Due to cultural preferences, users' time availability, and the lack of evening activities, the most "comfortable" hours were not voted as the preferred visiting hours (18:00 on warm day and 13:00 on cold day).

Finally, a practical list of recommendations for both critical dates was complemented with a set of simulations to validate their performances. The explorative proposals considered CSUD, placemaking and the recovered users' desire for the area. The implementation of new activities involves using more temporary interventions, which simultaneously create more "comfortable" spaces and attract more people. The study is an essential reference for decision-makers and designers to develop more comfortable and attractive public spaces.

Keywords

Outdoor Thermal Comfort, microclimate, ENVI-met , PET, MRT, public space, temporary interventions.

Originality statement. I hereby declare that this Master's dissertation is my own original work, does not contain other people's work without this being stated, cited and referenced, has not been submitted elsewhere in fulfilment of the requirements of this or any other award.

Signature

Dedicated to my mother, for always supporting my professional and personal development. Also, to my cousin Tony and my uncle Jhonny, for their inspirational strength throughout life.

TABLE OF CONTENT

ACKNOWLEDGEMENT

All my gratitude to my supervisors Dr. Eeva Aarrevaara and Dr. Denise Duarte. Thank you for your time, patience, and enthusiasm throughout these months. I couldn't have asked for a better duo for my thesis topic.

Thank you, Dr. Rohinton Emmanuel, for sharing your knowledge and experiences during my research. Moreover, thank you and the European Union and the Erasmus Mundus Scholarship for letting me participate in the MUrCS programme. Thank you for allowing many other professionals worldwide to gain significant knowledge that will help us work towards sustainability together.

Thanks to all the MURCS lecturers and staff.

A special mention to Nusrath Mahroof, Carolina Gusson and Paula Shinzato for their guidance in ENVI-met.

My gratitude also to Timo Arasola and Anne Karvinen-Jussilainen, who showed me the Market Square from their own eyes and shared valuable information. Market Square is indeed the "heart of the city". *Kiitos!*

I would also like to extend my appreciation to my friends Roberto, Keya, Maria, Kilian, Luisa, Lucía and Carlota, for helping me during the field survey and for your emotional support.

Thanks to my MURCS family for making these two years unforgettable.

Finally, I want to express gratitude to my family and my boyfriend for accompanying me throughout this time, despite being so far away.

LIST OF FIGURES

LIST OF TABLES

LIST OF GRAPHS

Chapter 1: Introduction

1.1. Rationale / Problem Statement

Climate change has shown a rapid and dangerous temperature rise in the last years (IPCC, 2014a). Moreover, the RCPs present a general ambiguity and uncertainty related to the projection of how much will the temperature increase (Nouri et al., 2018). In parallel, cities are already dealing with the effects of climate change, like constant heatwaves, which expose people to the risk of illness and death (Campbell et al., 2018). Thus, there is a need to find adaptation measures that cope with the speed of changes and allow resilience.

The temperature rise in high-latitude cities has not been considered a problem for many years (Suomi & Kayhko, 2012; Yan et al., 2020), but recent projections have raised awareness. In Finland, the temperature is expected to be 1.5 times higher than the global average temperature rise (Ministry of the Environment and Statistics Finland, 2017).

Different authors agree that outdoor spaces are potential contributors to alleviate the built environment's climatic impacts and incorporate climate change adaptive responses (CABE & Practitioners 2011, Emmanuel, 2016, Nouri & Costa, 2015). Its relevance relies on being part of the public realm and impacting microclimate and outdoor thermal comfort. Moreover, attractive public spaces also generate social, cultural, and economic benefits (Cheung & Jim, 2018; Madden & PPS, 2001), and have been a focus of attention during the COVID19 pandemic (Gehl, 2020; Gehl, 2021)

Additionally, studies have demonstrated that outdoor thermal comfort relates to users' behaviour and attendance in a place (Martinelli et al., 2015, Thorsson et al., 2004, Eliasson et al., 2007). The topic surrounds physiological and psychological aspects (e.g. experience, expectations or culture) (Johansson, 2016), leading to site-specific studies. The relationship of outdoor microclimate and thermal comfort has scarce studies in severe cold locations (arctic or subarctic area) (Yang et al., 2020).

In this same line, Climate-Sensitive Urban Design (CSUD) uses design tools to create pleasant spaces from the climatic perspective and mitigate the outcomes of urbanization (Oke et al., 2017). A good design should include adaptive/responsive measures and diversity in the urban forms to respond to expected changes in weather and seasons. Additionally, most studies cover winter or summer (Gatto et al., 2020; Yilmaz et al., 2021; Maharoof et al., 2020), so there is also a gap in studying the transitional seasons (spring and fall). The main CSUD strategies are vegetation, water and misting and shelter canopies. Nevertheless, temporary CSUD have not received enough attention from a climatic perspective (Nouri et al., 2018).

Temporary elements in the public realm can be found in every city in different contexts (Duarte, 2016; Lin, 2016; Nouri, 2015). Examples include parklets, urban furniture, street markets, sun sails and moveable vegetation boxes. They can be formal or informal, designed or spontaneous,

decorative or functional. Moreover, they can be seen as experimental, low-cost and community engagement elements.

Market Square in Lahti, Finland, is an excellent example of temporary elements in a public space. The area has multiple events around the year, being some seasons more active than others. Additionally, the area has a historical significance that limits constructions in the site and reinforces ephemeral elements. The space attracts different people, especially for its activities and when there are optimal weather conditions.

1.2. Aim and Objectives

The present study aims to evaluate the influence of existing temporary interventions in the microclimate and outdoor thermal comfort in Lahti's Market Square during spring. Also, to discuss other alternatives with a more climate-sensitive approach.

The objectives to cover are the following:

1. Identify the existing temporary interventions in the Market Square and how are they developed.

2. Understand local meteorological characteristics and variations in recent years with an annual and seasonal insight, especially in spring.

3. Analyse the impact of temporary interventions on outdoor thermal comfort and microclimate in spring.

4. Investigate the users' behaviour and opinions about outdoor thermal comfort and activities in the study area.

5. Identify, if any, which changes would be necessary to improve the plaza and make it more climate-sensitive using temporary elements.

6. Establish a background document that helps develop public spaces with climate sensitivity strategies using temporary interventions according to the season.

1.3. Methodology Outline

Overall, the methodology follows Correlational and Simulation research strategies. The study used mixed methods. Qualitative data includes interviews, pictures and layouts, while quantitative data uses meteorological records, a questionnaire, traverse surveys, and computer-based simulations.

The methodological framework is divided into four general streams. The first one covers a general understanding of the study area. Then, the second one presents the outdoor thermal comfort and microclimatic analysis. The third stream includes the users' behaviour and

opinions of the site. Later, a general comparison of the streams leads to specific strategies for spring's critical cold and warm days. Finally, the strategies are implemented in two climate-sensitive proposals.

1.4. Dissertation Structure

Chapter 1 introduces the problem and the study area. It also defines the research question, aim and objectives.

Chapter 2 presents a literature review that starts with a panoramic view of Climate Change for later contextualizing it in the urban field. Then it shows the relevance of microclimate and outdoor thermal comfort in public spaces. Additionally, it presents a general definition of temporary interventions. Finally, it states four knowledge gaps.

Chapter 3 gives an overview of the study area and the city.

Chapter 4 presents the methodology and breaks down its different steps. It also exposes how would the objectives be covered and the reasons for the decisions made in the process.

Chapter 5 presents the processed results divided by topics. It covers a general understanding of local weather, as well as users' behaviour and opinions. Additionally, temporary interventions are identified in two events (monthly market and daily market). Finally, it presents a microclimate and outdoor thermal comfort study for two critical days.

Chapter 6 discusses the connections between the results and the literature review, as well as personal interpretations. It includes a summary of the main findings for each critical day, which allow special proposals for the site. Finally, limitations are exposed.

Chapter 7 covers the conclusions and the recommendations for future studies.

Chapter 2: Literature Review

2.1. Climate change: a global problem with local implications

Climate change is a reality with severe consequences for human's health. In the last 100 years, the planet shows a rising temperature trend that has caused an increase in frequency, intensity and duration of heatwave's (IPCC, 2014a, Madsen & Hansen, 2019). Consequently, mortality and morbidity related to heat exposure have increased (Campbell et al., 2018).

Climate change's temperature rise is a fact, but there is uncertainty related to how much more and in how many years (Nouri et al., 2018; Duarte, 2015; IPCC, 2014a), mainly because it is an anthropogenic-driven consequence. Its future depends on how Greenhouse gases (GHGs) are managed. The IPCC (2014a) developed four different Representative Concentration Pathways (RCPs) scenarios considering the tendencies in GHGs emissions until the end of the century (Figure 1 and Figure 2); all cases show a global increase in temperature. Even though international efforts are not to surpass +2 C° considering the "Paris Agreement", different nations are not covering their pledge (climateactiontracker.org, 2020), leading to more doubts about the future.

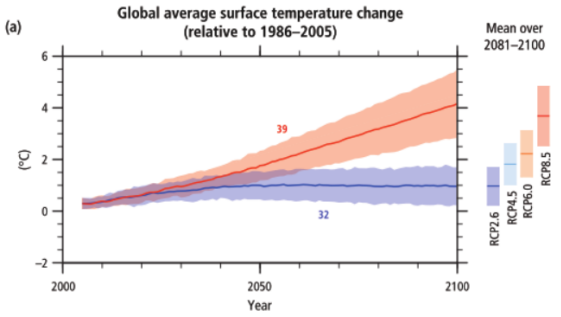


Figure 1. Global average surface temperature change. (IPCC, 2014a)

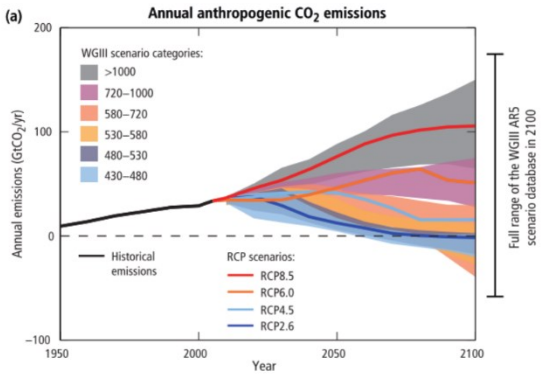


Figure 2. Emissions of carbon dioxide (CO2) alone in the Representative Concentration Pathways (RCPs) (lines) and the associated scenario categories. (IPCC, 2014a)

In the Northern Hemisphere, the last 30 years have been the warmest period of the previous 1400 years (IPCC, 2014a). Despite its multiple efforts against Climate Change and ambitious goals, the Nordic countries[1] will be one of the most affected ones with the rise of temperature in any IPCC scenario (Figure 3). The Nordic Action Plan (Bird, 2017) exposes that the region has "performed a sustained reduction of greenhouse gas emissions while promoting sustainable economic growth and employment". It also mentions that part of its success is governments' recognition of climate change, insertion of mitigation and adaptation policies, and social acceptability.

[1] *The Nordic Region consists of Denmark, Norway, Sweden, Finland, and Iceland, as well as the Faroe Islands, Greenland, and Åland.*

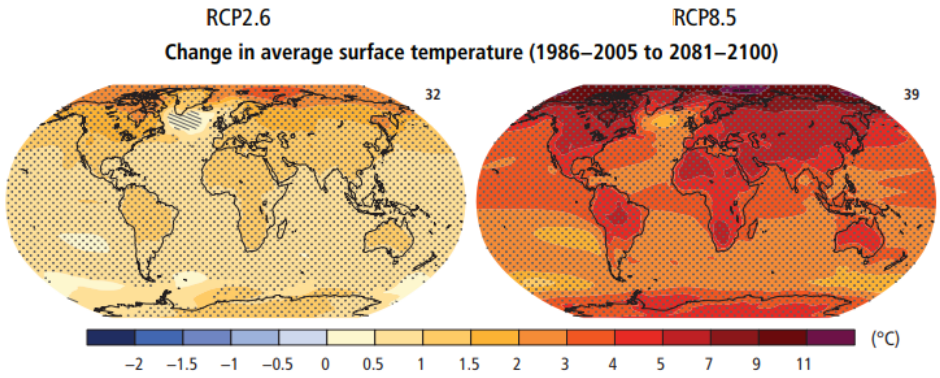


Figure 3. Change in average surface temperature based on multi-model mean projections for RCP2.6 and RCP8.5 (IPCC, 2014a).

In Finland, the temperature increase is expected to be about 1.5 times higher than the global average temperature rise. Figure 4 exposes a rise of +3°C to +6°C between 1971–2000 and 2070–2099 (Ministry of the Environment and Statistics Finland, 2017). Aside from heatwaves, frost days will decrease, and winter temperature will rise, leading to more seasonal affective disorder, more risk for slipping injuries and traffic accidents. Nevertheless, assessments mention positive impacts as reducing the energy demand for heating, tourism benefits for longer summers, and lesser mortality from cardiovascular and pulmonary diseases during winters (Ministry of the Environment and Statistics Finland, 2017; Ministry of Agriculture and Forestry, 2014).

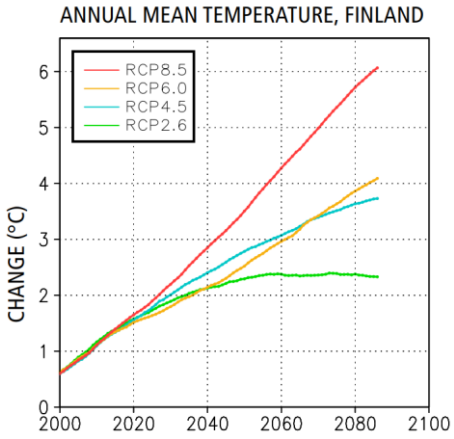


Figure 4. Change in the annual mean temperature (°C) predictions for Finland 2000–2085 compared to the average values in 1971–2000, considering RCPs scenarios (Ministry of Agriculture and Forestry, 2014)

2.2. Cities: their role in Climate Change

Actions for limiting climate change focus on two spheres: adaptation and mitigation. While mitigation attention is on GHGs emissions reductions, adaptation involves preventing inevitable climate change consequences. Both aspects need to be executed in parallel because progressive mitigation will allow efficient adaptation and sustainable development (IPCC, 2014a). The establishment of concrete plans combines government decisions (local, state, and national), civil society agents, the public sphere (Duarte, 2015), and international agreements.

Furthermore, it requires a legal framework that facilitates its implementation. According to Mills (2016), cities have a superior capacity for developing these plans than rural areas because they have more developed government systems. Urban areas have successfully started the implementation of their adaptation and mitigation plans like Lisbon (Nouri et al., 2018), Barcelona (Ajuntamiento de Barcelona, n.d.) and Lahti (Green Lahti, n.d.).

Simultaneously, the cities severely impact climate change by altering radiation and wind patterns, resulting in phenomena like the Urban Heat Island (UHI) (Emmanuel, 2016). Globally, UHI varies between 0.4 °C and 11 °C, with an average of 4.1 °C (Santamouris, 2015). Additionally, the UHI effect amplified the health consequences previously mentioned (Tomlinson et al., 2011). UHI effect varies according to the season, time of day, city's geometry, and anthropogenic heat release (metabolic heat, traffic, and buildings) (Romero et al., 2020).

UHI is not considered a severe problem in high-latitude cities (Suomi and Kayhko, 2012). Even more, there is a perception of positive effects (Yan et al., 2020). Nevertheless, Climate Change predictions brought new perspectives in the region to understand the parameters and processes that govern urban climatic conditions.

Different authors highlight local analysis's importance in defining adequate actions (Maharoof et al., 2020; Emmanuel, 2016). Even today, projections of future climates are made, excluding the effects of local warming, as the UHI (IPCC, 2014b). Moreover, bottom-up approaches have called attention to find adaptation models that can be more accurate to the local context. It allows a detailed study of the climatic situation and other social and environmental factors (Nouri et al., 2018).

2.3. A perspective between the buildings

2.3.1. Microclimate and outdoor thermal comfort

The microclimate results from atmospheric conditions and physical characteristics of a site, which differs from surrounding areas (Erell et al., 2011, Yilmaz et al., 2021). The most significant variability in microclimates exists close to the surface in the Urban Canopy Layer (UCL) (Oke et al., 2017) (Figure 5). It is complex because it presents various fabrics, materials, dimensions, buildings' geometry, and human activities.

One of the main focuses of microclimate is human wellbeing. Studying the urban microclimate could improve live quality of residents by implementing appropriate solutions (Erell et al., 2010). Figure 6 reveals that human health and comfort get affected directly and indirectly by different urban and environmental variables.

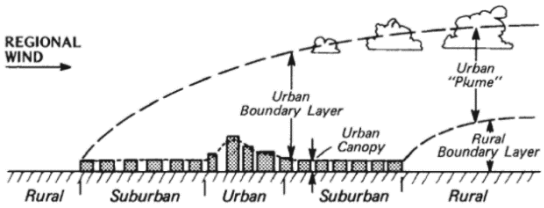


Figure 5. Schematic representation of the urban atmosphere illustrating a two-layer classification of urban modification (Oke, 1978)

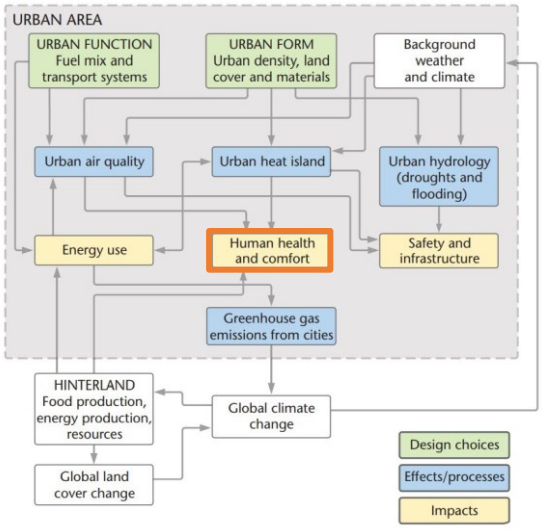


Figure 6. Schematic diagram of design choices, effects and impacts on the urban and global scale. (Oke et al. et al., 2017)

Thermal comfort is a mental state where the person is satisfied with the thermal environment (ASHRAE, 2009); consequently, it is a human being's response to the microclimate conditions. When a climatic stimulus appears, the person will apply specific measures (consciously or not) to feel thermally comfortable (sweating or searching for shadow) (Nouri et al., 2018; Oke et al., 2017; Erell et al., 2011; Brown, 2010). Thermal stress combines different environmental stimuli (radiation, air temperature, humidity and wind speed), which the body responds with thermal strains. When the heat storage is close to zero, the person has reached his thermal comfort. The changing climatic conditions have dangerously altered thermal comfort; heatwaves cause thermal stress, discomfort, hyperthermia, and death (Oke et al., 2017; Duarte, 2015).

Outdoor scenarios have gotten attention in recent years. It is well known that the outdoor microclimate parameters are directly affected by the urban geometry (Emmanuel et al., 2007). Studies in this area can help optimise public spaces' design, improve city liveability, and save heating and air conditioning energy inside buildings by spending more time outdoor (Yang et al., 2016). Santamouris (2016) identified four cluster studies for outdoor thermal comfort:

- Spatial distribution of the outdoor thermal comfort levels
- Evolution of outdoor thermal comfort in a specific place considering the interannual temperature increase.
- Outdoor thermal comfort conditions during extreme weather conditions
- Future outdoor thermal comfort in different areas considering Global warming

Several outdoor thermal comfort indexes are used for outdoor studies; one of its divisions is known as rational indexes. They generally use the heat balance equation of the human body and consider the environmental variables that affect thermal comfort (Air temperature, humidity, mean radiant temperature and wind speed) (Table 1 and Figure 7) (Johansson, 2016). Some were initially for indoor studies but adapted to the outdoor, e.g., PMV (Gatto et al., 2020). Adaptation to the thermal environment also affects the applicability of thermal comfort indexes, which means that the local population tolerates better weather than external individuals. Therefore, some studies aim to calibrate the indexes according to each context, applying questionnaires related to thermal perception and micrometeorological measurements. However, these indexes have been criticised due to the lack of assessment under transient exposure and not considering psychological factors (Eliasson et al., 2007).

On the other hand, Mean Radiant Temperature (MRT) is often used to study outdoor thermal comfort (Gatto et al., 2020; Lindberg, 2008; Martinelli et al., 2015). Its value represents the impact of all short- and long-wave radiation fluxes on the human body, and its understanding is essential when analysing thermal comfort (Matzarakis et al., 2007).

Table 1. Commonly used Rational indexes for Outdoor Thermal Comfort. (Own elaboration, 2021 based on Oke et al., 2017, Erell et al., 2011 and Johansson, 2016)

Name	Characteristics
Predicted Mean Vote (PMV)	• Initially conceived for indoors thermal comfort • Considered clothes and activity • Values: very cold (~3) to very hot (+3) • Commonly used in outdoor thermal comfort studies
Physiological Equivalent Temperature (PET)	• Intended for outdoor thermal comfort • It is defined as the air temperature at which the energy balance for typical indoor conditions is balance with the same mean skin temperature and sweat rate as calculated for the complex outdoor conditions • It assumes standard clothing (0.9 clo) and activity (80W) • Expressed in C° • Commonly used in outdoor thermal comfort studies
UTCI	• It is an outdoor index developed to be validated in all climate types and all the seasons • Expressed in C° • It uses an advanced clothing model • The metabolic rate used is a constant (135 W/m2), which corresponds to walking at a speed of 1.1m/s. • It is the most recently developed thermal index. Compared to other indexes, few studies have used it.

PMV	PET	Thermal perception	Grade of physiological stress	Universal Thermal Climate Index (UTCI) (°C) range	Physiological responses
		Very cold	Extreme cold stress	< 40	Decrease in core temperature
−3.5	4			−27 to −40	Shivering, average skin temperature will fall below 0°C if exposure is sustained
−2.5	8	Cold	Strong cold stress	−13 to −27	Face temperature < 7°C (numbness), core to skin temperature gradient increases
		Cool	Moderate cold stress	0 to −13	Vasoconstriction, exposed skin temperature < 15°C
−1.5	13	Slightly cool	Slight cold stress	+9 to 0	Localized cooling, need for gloves
−0.5	18				
		Comfortable	No thermal stress	+9 to +26	Comfortable, sweat rate < 100 g h^{-1}
0.5	23				
1.5	29	Slightly warm	Slight heat stress	+26 to +32	Slight heat stress
		Warm	Moderate heat stress	+32 to +38	Positive change in rate of sweating, and of skin temperature
2.5	35	Hot	Strong heat stress	+32 to +38	Sweat rate > 200 g h^{-1}
3.5	41			+38 to +46	Small core to skin temperature gradient (< 1 K). Sweat rate increase (> 650 g h^{-1} at limit)
		Very hot	Extreme heat stress	> 46	Increase in core temperature

Figure 7. Ranges of thermal indexes. (Oke et al., 2017)

Outdoor studies have not been widely developed in severe cold areas (Yang et al., 2016). Nordic countries studies had used PMV, PET, MRT and UTCI (Table 2). A survey in Umea, Sweden, proposed contextual rearrangements of Thermal Sensation Values (TSV) scales in PMV, PET, and UTCI (Yang et al., 2016). Nevertheless, PMV overestimated TSV and was not suitable for the study. Table 3 shows the calibrated values obtained for PET and UTCI. Results expose that local people are slightly more sensitive to warmer environments than non-local persons. However, they focus on neutral to very hot temperatures because the study developed during summer.

Table 2. Outdoor thermal studies examples in Nordic countries (Own elaboration, 2021)

Title	Authors	Year	Context	Thermal Comfort Index
Thermal bioclimatic conditions and patterns of behaviour in an urban park in Göteborg, Sweden	Thorsson et al.	2004	Göteborg, Sweden	PMV and MRT
Potential changes in outdoor thermal comfort conditions in Gothenburg, Sweden due to climate change: the influence of urban geometry	Thorsson et al.	2011	Göteborg, Sweden	PET and MRT
Outdoor thermal comfort under subarctic climate of north Sweden – A pilot study in Umeå	Yang et al.	2016	Umeå, Sweden	PMV, PET and UTCI
Impact of Urban Vegetation on Outdoor Thermal Comfort: Comparison between a Mediterranean City (Lecce, Italy) and a Northern European City (Lahti, Finland)	Gatto et al.	2020	Lahti, Finland and Lecce, Italy	PMV and MRT

Table 3. Relationship between mean TSV, PET and UTCI. (Own elaboration, 2021 based on Yang et al., 2016

Thermal sensation (TSV)	PET (Umea, Sweden)	Stress category (TSV)	UTCI (Umea, Sweden)
Neutral (-0.5-0.5)	10-17	No thermal stress (-0.5-0.5)	2.26
Slightly warm (0.5-1.5)	17-24	Moderate Thermal stress (0.5-2.5)	26-32
Warm (1.5-2.5)	24-32	Strong thermal stress (2.5-3.5)	32-38
Hot (2.5-3.5)	32-39	Very strong thermal stress (3.5-4.5)	38-46
Very Hot (>3.5)	>39	Extreme thermal stress (>4.5)	>46

2.3.2. Users' Behaviour

Several studies demonstrate the relationship between environmental factors, outdoor thermal comfort, and user's behaviour in public spaces. A study in a plaza in Rome (Martinelli et al., 2015) evidenced significant attendance in the plaza in shaded areas during summer, where PET was lower (Figure 8). Similarly, in New York, the occupation of public spaces showed a significant correlation with environmental and design conditions like sun, wind, trees, and water (Whyte, 1980). Both studies exemplify "behavioural adaptation", which refers to a person's adjustment to the environment to search for their comfort (Lin, 2009; Johansson, 2016).

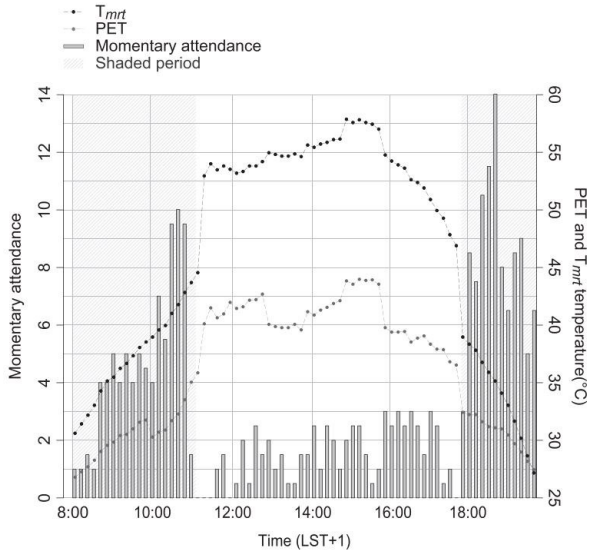


Figure 8. Mean of attendance compared with PET and MRT values, with 10 min resolution. (Martinelli et al., 2015)

Aside from the physiological factors, the psychological aspect has a vital role in outdoor thermal comfort, e.g. available choice, culture, memory (Johansson, 2016; Martinelli et al., 2015). Extreme and long winters in severe cold areas generate that people cherish summer and have more outdoor activities (Yang et al., 2017). Studies in Sweden have shown high expectations to solar radiation, preferences of "warm" conditions (Thorsson et al., 2004) and a significant influence of air temperature, wind speed and clearness index (cloud cover) in people's place perceptions and place-related attendance (Eliasson et al., 2007).

During the present pandemic situation, the importance of outdoor spaces has won interest. Gehl Office (2020) surveyed lockdown and post-lockdown in Copenhagen; in a questionnaire, the respondents mentioned that local public areas were vital for their mental health during this time. They also found that people are using their local meeting spaces more than before (Figure 9). Public spaces are essential in the recovery of COVID19, they need to be appropriately adapted, and the government must look at them strategically (Myrick, 2020).

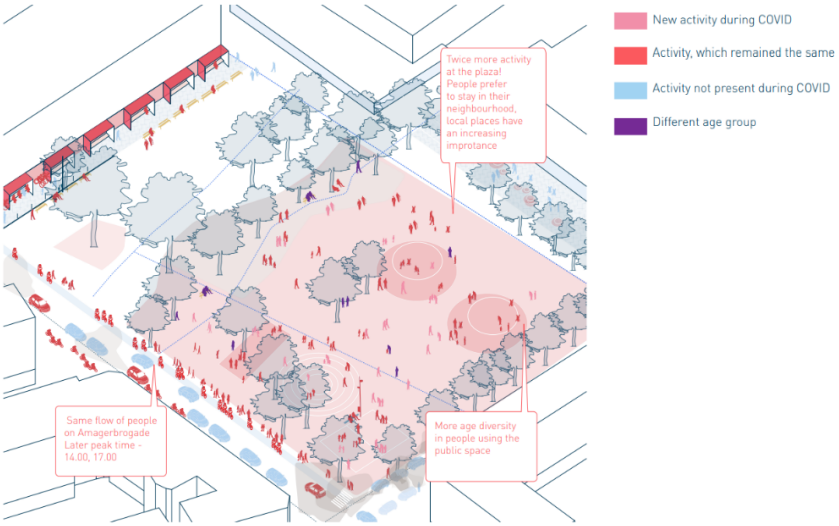


Figure 9. Sundbyøster Plads (Copenhagen) Survey during COVID19 (Gehl, 2020).

2.3.3. Climate-Sensitive Urban Design

Climate-Sensitive Urban Design (CSUD) uses design tools to create pleasant spaces from the climatic perspective and mitigate the outcomes of urbanization (Oke et al., 2017; Emmanuel, 2016). In this sense, the design or redesign of public spaces is an opportunity to incorporate Climate Change adaptations actions (Nouri & Costa, 2017). Moreover, outdoor spaces encourage pedestrian traffic and outdoor activities and contribute significantly to urban liveability (Gatto et al., 2020).

Different authors expose the need to collect and analyse the environmental data before the design process. The data includes wind speed and pattern, ambient temperature, relative humidity, global radiation, surface temperature and shadow pattern (Nouri et al. 2018; Maharoof et al. 2020, Gatto et al., 2020; Johansson & Yahia, 2010). Some authors collect in-situ data (Nouri et al., 2018; Maharoof et al., 2020); others use local meteorological station data (Gatto et al.). The Sky View Factor is also commonly used to measure the radiative flux leaving the surface (Maharoof et al., 2020, Nouri et al., 2018, Duarte, 2016). Then the data is processed and introduced to programs like ENVI-met or RayMan to have a more detailed understanding of the microclimate.

Vegetation presents essential qualities for outdoor thermal comfort: evapotranspiration processes, sun reflection, solar protection, alteration of wind flow retention of particles (Duarte, 2016; Gatto et al., 2020). Different studies have shown that greenery has better thermal comfort effects in summer than in winter (Gatto et al. 2020, Yilmaz et al., 2021). Hence, their implementation needs evaluation, especially in cooler climates (Nouri, 2015). Additionally, planted areas in a city show effects also in the surroundings and mitigate UHI (Cheng and Wong, 2006)

Another commonly suggested element for microscale CSUD is shelter canopies. They restrain the solar access, reducing short wave radiation fluxes, the temperature of shaded surfaces and long-wave radiation. It affects the MRT directly and has a general cooling effect (Emmanuel et al., 2021). However, depending on the geometry, materials, and wind patterns, the outcome can change (Nouri, 2015; Lin, 2016). In Turkey, semi-open canopy street canyons are suggested during winter to provide high thermal comfort but not during summer (Yilmaz et al., 2021). Nevertheless, in Glasgow, the use of sun sails showed a significant reduction in PMV during summer (Maharoof et al., 2020).

Shadow is an essential element in reducing the MRT, generating positive outdoor thermal comfort in a warm context (Emmanuel et al., 2007). Shade can be obtained through trees, horizontal shading, street orientation and buildings height and density (H/W ratio). During summer, a comparative study in Hong Kong between a tree and a concrete shelter showed that both had cooling effects (Cheung & Jim, 2018). However, the tree indicated better performance in air temperature and UTCI, while PET presented similar values in both cases.

CSUD proposals need to be site-specific for considering the cultural aspects. Moreover, the design must evaluate different seasons and adapt if required (Yilmaz et al., 2020). As general strategies, design should focus on deviating wind during winter; while sun protection and more wind circulation during summer (Brown, 2011). Nevertheless, subarctic contexts suggest enhancing sunshine and weakening wind (Yang et al., 2017). The function of the street will also lead to the definition of the proposals (Oke et al., 2017).

Finally, there is a consensus that public spaces' design must offer a diversity of microclimates so users can select the area where they find more thermal comfort (Thorsson et al., 2004; Martinelli, 2015; Oke et al., 2017).

2.4. Temporary interventions: solutions for specific needs

When identifying temporary elements in the outdoor environment, different types can be found. They are used in various fields with specific purposes; however, it is possible to find similarities.

Aligned with CSUD, temporal interventions can attack critical climatic periods, like heatwaves, in public spaces. Nouri (2014) identifies Ephemeral Thermal Comfort Solution (ETCS) in temporary shelter canopies. They improve thermal comfort levels, increase users' activities, and has a reduced budget. Additionally, temporary canopies are an alternative when the implementation of greeneries has obstacles (Martinelli et al., 2015).

Spontaneous greeneries are found in the formal and informal contexts (Figure 11). From an urban and environmental point of view, they improve urban life (Duarte, 2016). Green walls, community gardens, parklets, rooftop gardens and balconies are some of the identified shapes of spontaneous greeneries. Other temporary characters like street markets, community celebrations or

sports also effectively transform the public spaces. For Casagrande (2013), the sum of punctual micro-scale interventions inserts nature back in the city.

The Placemaking process includes implementing short-term experiments as one of its principles because it is low-cost, has a high impact for improving public spaces, and generates new uses and revenue for sites in transition (Project for Public Spaces, Inc 2018). Moreover, the theory exposes how temporary projects serve as feedback for ongoing or future long-term projects, mostly related to a place's liveability. However, Nouri and Costa (2017) considered that placemaking theory needed to incorporate the response to climatic aspects, so they restructured the original diagram (Figure 10).

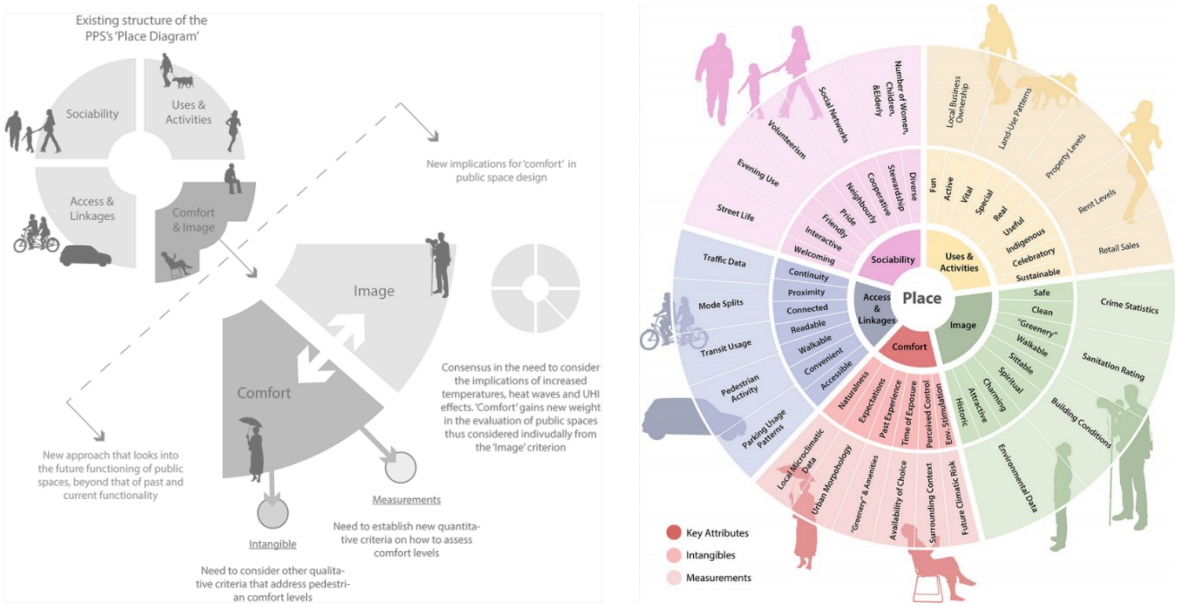


Figure 10. Restructured Place Diagram. (Nouri and Costa, 2017)

Temporary or tactical urbanism has similarities with the previous concept. However, it aims to be short-term to respond to specific needs and impact urban socio-economic environments (Andres & Zhang, 2020). Projects can start from the governments, the communities or a combination of both. Considering that open spaces are the "public life lifeline" during the current pandemic, temporary urban solutions became crucial strategies for cities adaptation (Gehl, 2020). Shops and restaurants are translating to open spaces. Meanwhile, rotating markets adapted for having safe distances.

Finally, art installations have high social engagement and appropriation of space (Zecevic, 2017). In this case, temporality responds to the constant changes in everyday life.

Combining all the references exposed, temporary interventions in the city respond to a particular purpose in a specific time and context. Additionally, they have generally low-cost. Even though they have a reduced scale, they can have a superior impact. Finally, the community is involved as creators or users; hence, temporary interventions significantly affect human activity in public spaces.

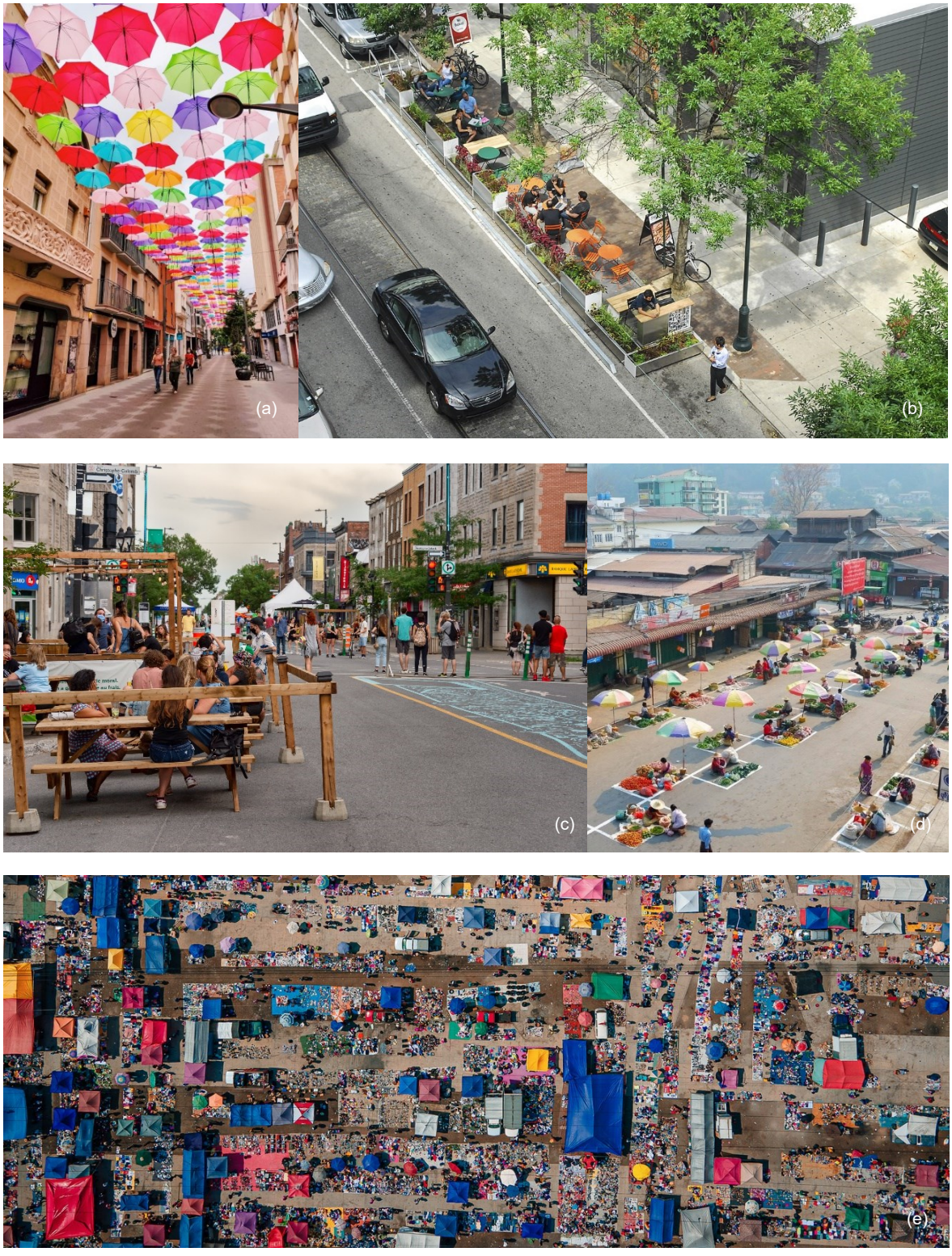


Figure 11. Collage of temporary interventions (a) Umbrella Sky Project-Spain, b) Parklet in Beacon, NY, (c) Covid 19 intervention in Montreal, (d) Adaptation of a street market during Covid 19 Kalaw, Myanmar, (e) Informal Mexican Street Market "Tianguis Eje 6 y Periférico" (Own elaboration, 2021 images retrieved from Umbrella Sky Project, 2021; City of Beacon, 2020; evergreen.ca, 2021; Chan Myae Aung, 2020; Gonzalez, 2021).

2.5. Knowledge Gaps

- Multiple investigations considered outdoor thermal comfort; however, the evaluations' results have not been effectively inserted into urban planning and design. Therefore, there is a gap in the application and theory of outdoor thermal comfort strategies. Some reasons lie in controversies about applying different methods (PET, ICU or PMV) and considering that the studies are still at an early stage. Nevertheless, more studies will support the field evolution and the generation of more design and planning strategies.

- Shelter canopies have not been investigated in the same measure as vegetation in outdoor thermal comfort. Trees and vegetation have become a popular topic in the last years, allowing the identification of its multiple benefits. As a result, different municipalities have introduced them in their urban plans and climate change adaptation measures. Exploring shelter canopies, especially as temporary solutions, might open new effective and low-cost thermal comfort possibilities.

- A reduced number of studies related to outdoor thermal comfort in severe cold weather locations, such as Finland, compared to tropical areas. The existing climatic emergency requires relevant studies to implement adaptation and mitigation measures. Additionally, public spaces have been a facilitator for the cities during the current pandemic. Therefore, it is essential to improve their design considering thermal comfort parameters.

- Research highlights the importance of seasonal variation in outdoor thermal comfort, but studies mainly focus on summer and winter. There is a gap in transitional seasons (spring and fall), especially in Finland with contrasting weather.

Chapter 3: Context

3.1. Lahti, Finland

Lahti is in southern Finland and is the capital of the Päijät-Häme region (Figure 12). It is considered a Warm Summer Continental Climate Dfb class according to Köppen's climate classification, with warm to hot summers and cold winters (Gatto et al., 2020). Most of the city is covered by green and blue areas. Lake Vesijarvi defines a significant part of its landscape and has an important influence on the climate.

Lahti was a village in 1445, but in the 1870s, incorporating an international railway gave it more attention (lahtiguide.fi, n.d.). A great fire in 1877 and its redevelopment transformed Lahti into a market town in 1878, and in 1905 it became a city. In the 70's Lahti was an industrial city, causing fast population growth and severe environmental damages affecting mostly Lake Vesijarvi (Green Lahti, n.d.). Nevertheless, since the 80's several ecological restoration projects have been successfully executed, showing strong planning and implementation mechanisms. It became the European Green Capital 2021.

Table 4. Lahti's Data sheet (Own elaboration, 2021 information retrieved from Stat.fi, 2019; Suomi, 2018 and Pirinen et al., 2012)

Topic	Data
Population	119 823 (2019)
Total area	517.63 km2
Land area	459.43 km2
Inland waters area	58.20 km2
Annual average temperature	4.5°C
Typical Coldest month and average temperature	February, -7.00 C°
Typical Warmest month and average temperature	July, 17.2°C
Lowest historical temperature	-35.2 °C (1987)
Highest historical temperature	35.00°C (2010)
Average annual rainfall	636 mm
Typical Driest month	April (28 mm)
Typical Wettest month	July (77 mm)

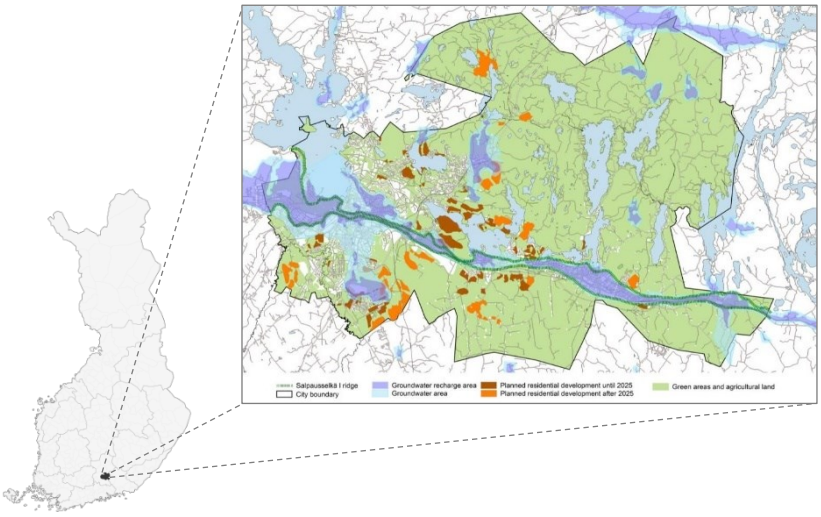


Figure 12. Lahti location and land use map (Own elaboration, 2021 image retrieved from Lahden kaupunki, 2019).

3.2. Lahden Tori (Lahti's Market Square)

Lahti's plan for 1878 shows the Market Square as the city's central point, where old medieval merchant routes were conveyed (Figure 13) (rky.fi, 2009.). The original grid plan marks the city's development until the present, with Aleksanterinkatu and Mariankatu as the main streets. A "ceremonial axis" connects the Townhall (1912) and the Church of the Cross (1978), designed by architects Eliel Saarinen and Alvar Aalto, respectively. Both landmarks are on elevated terrains, during the Market Square in the lowest point. The area is included in the National Cultural Heritage List RKY 2009. Currently, the city centre is densely built with a regular grid plan with asphalted streets and 4 to 8 storey stone houses (Figure 14).

Figure 13. Lahti town plan from 1878 by Alfred Caween (Caween, 1878).

Market Square is considered the most important venue for outdoor events, with a capacity of 12 000 people. (Lahti, n.d.). The place is very flexible and hosts various activities and events (Figure 15 and Figure 16). For several years, it has held a market on the first Wednesday of every month. In 2014, the area was renewed, including an underground parking lot (capacity 600 vehicles), drainage, electrical outlets, fibre optics, and lighting. It also included small buildings on the corners (cafe and stairwell, toilets, and offices). It has a cobblestone surface with a red-coloured path for accessibility. The perimeter presents rows of trees (*Tilia cordata Mill)* with an average height of 15 m (Gatto et al., 2020).

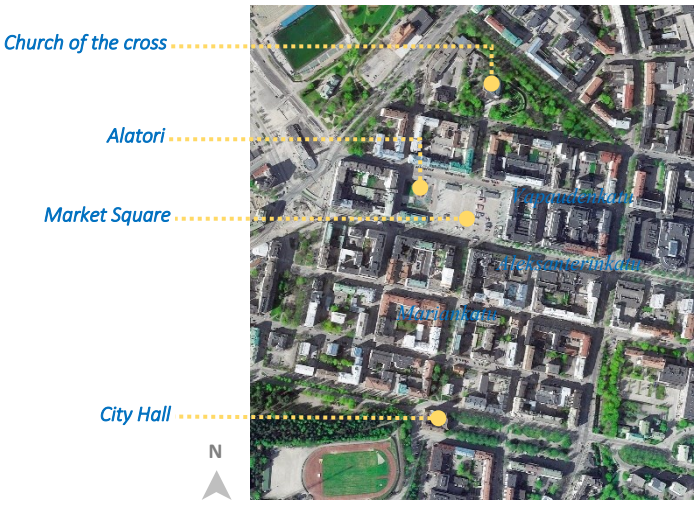


Figure 14. Aerial view of Market Square and surroundings (Own elaboration, 2021 image retrieved from Google Earth, 2019)

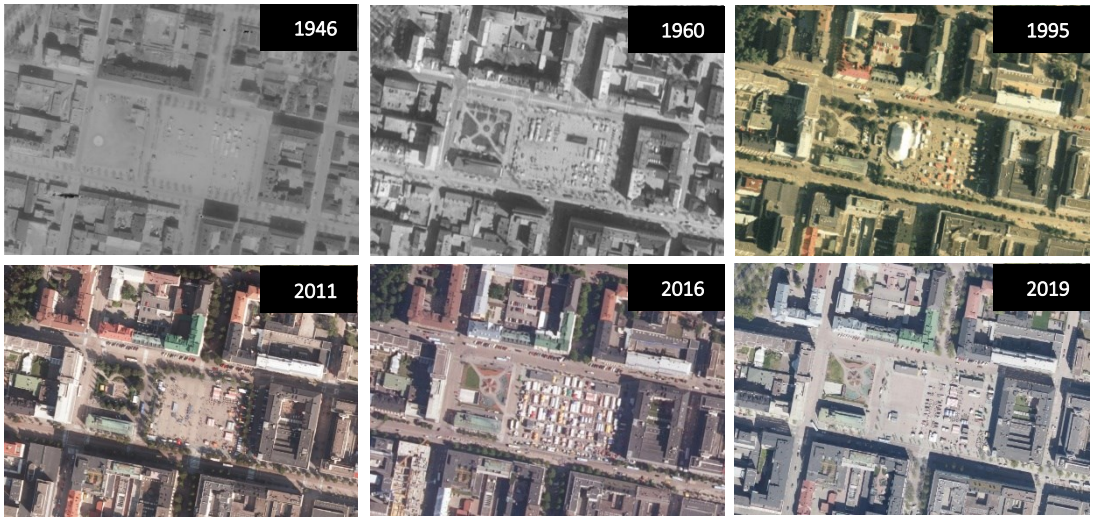


Figure 15. Collection of Aerial Photos of the Market Square (Own elaboration, 2021 images retrieved from kartta.lahti.fi, 2019)

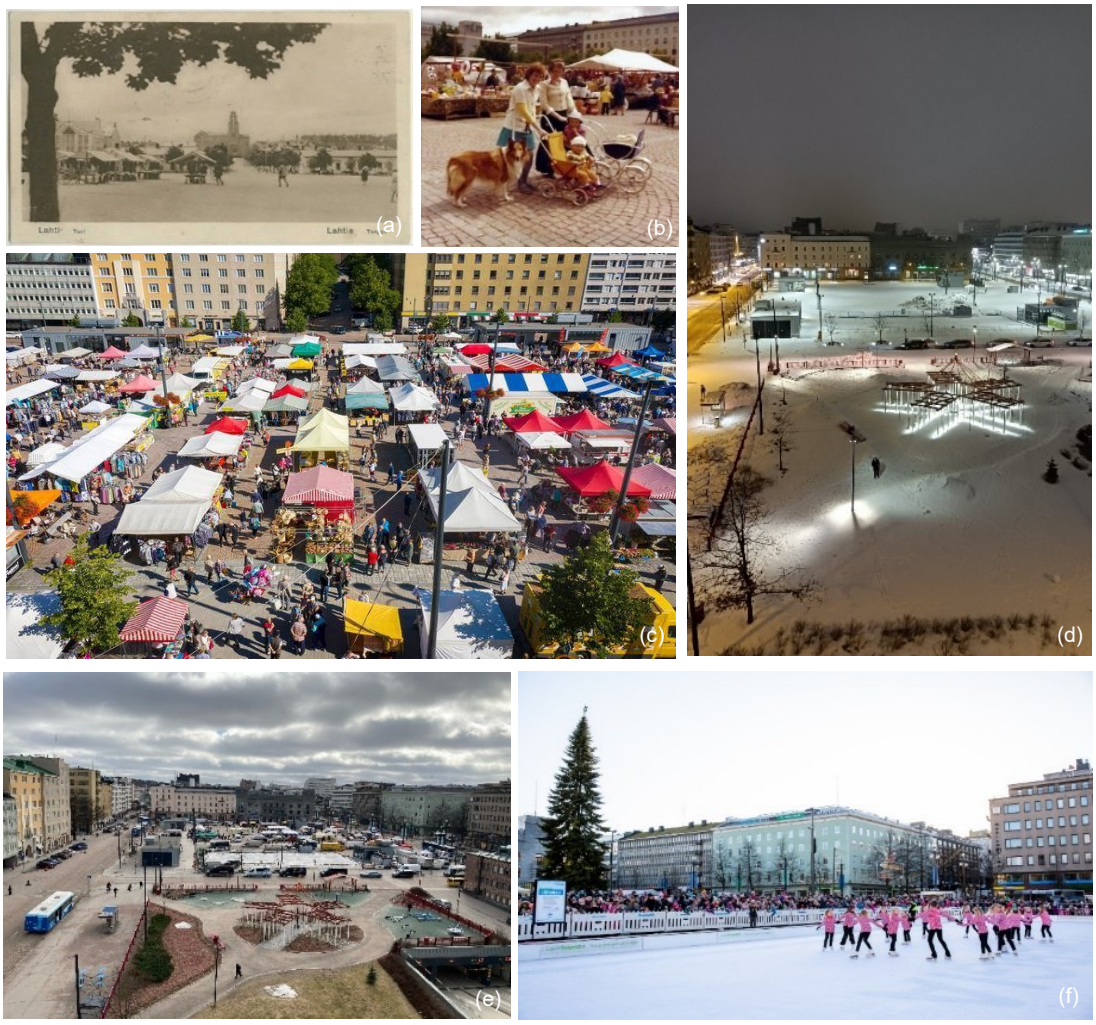


Figure 16. Photographic compilation of activities in the Market Square (a) 1910, (b) 1975, (c) Monthly Market, (d) winter 2021 during evening (e) Monthly Market April 2021, (f) winter activities with ice rink and Christmas tree (Own elaboration, 2021 images retrieved from Toivonen Seppo, 1910; Laitinen, 1975; Peurala, n.d.; greenlahti.fi, n.d.)

Chapter 4: Methodology

4.1. Research Philosophy, approach, and Framework

The literature review shows a connection between the outside thermal comfort and the design of the temporary interventions. Additionally, the user's behaviour related to the assistance is an indicator of outdoor thermal comfort. Finally, the appropriate climate-sensitive design validity depends on the season's meteorological characteristics and users' needs. As a result of the previous chapter, the following research question is proposed: *How do Market Square's temporary interventions influence the microclimate and pedestrian comfort during spring? Is it possible to find more climate-sensitive proposals?*

As mentioned in the literature review, the microclimate, thermal comfort, and climate-sensitive design are site-specific. Therefore, the research is based on a case study: Lahti's Market Square. The selection of the case study relies upon the multiple events and temporary interventions made around the year. The selection is reinforced for its historical and traditional relevance for the city. Furthermore, the study focuses on spring, a transitory season.

The methodology for answering the research question is divided into two sections. The first one follows a deductive approach. The variables include the weather, microclimate, user's behaviour and the temporary interventions. Additionally, it is comparative-correlational for using real-world variables and the intention to clarify their relationship (Groat and Wang, 2013). It is also a simulation research that analyses different scenarios (no interventions, daily market and monthly market) in the plaza during critical days (cold and warm) using ENVI-met.

The second section has an abductive approach (Groat and Wang, 2013). It includes exploring proposals based on the discussions in the previous section to improve the thermal comfort in the area. It is mainly simulation research in which proposals are introduced to ENVI-met to evaluate if there is an improvement in thermal comfort effects. The ENVI-met model's parameters were validated with field measurements and linear regression analysis.

The study employed mixed methods. On the one hand, the qualitative methods included interviews, photographs of the interventions and the market's layouts. On the other hand, the quantitative methods consist of online questionnaires, meteorological data records (annual and seasonal analysis), meteorological measurements for specific days (fixed station and traverse study), and microclimatic and thermal comfort values using computer-based simulations.

Figure 17 describes the study's framework and its connection with the initial research objectives. It is divided into three inputs: additional information, user's behaviour & opinions analysis, and thermal comfort & microclimatic analysis. Finally, comparing these topics will determine the need for improvement proposals for the site, represented as the graph's output. The data used for each input are exposed as four topics: additional information, users, meteorological data, and Market Square.

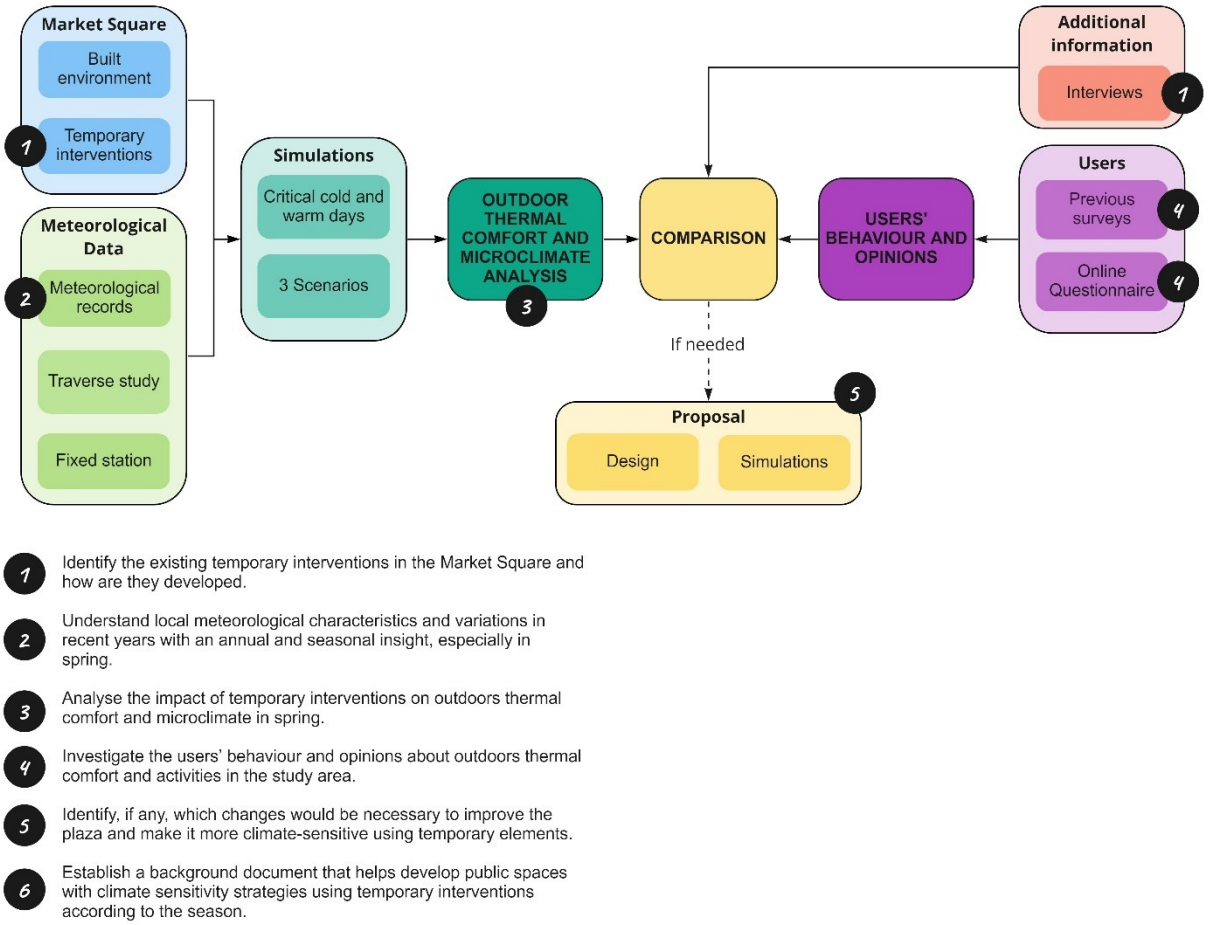


Figure 17. Connection of objectives and methodology's milestones (Own elaboration, 2021)

It is essential to mention that due to the current pandemic, the initial methodology needed to adapt. During the study, the Government included more restrictive measures like bars and restaurants' closure. The Market Square's host mentioned that the situation impacted their activities and public attendance. Therefore, the original face-to-face questionnaire needed to be changed to an online one, and the attendance count was deleted from the survey.

4.2. Market Square's Additional information

- Interviews

In-depth interviews were considered to cover Market Square's management, perception, responsibilities, future projects and other issues that were not found in other media. The interviewees were selected considering their relevant position and connection to Market Square. On the one hand, Timo Arasola, host of the Market Square for six years and CEO of Lahentori. On the other hand, Anne Karvinen, City architect of Lahti, coordinates specific Market Square projects. Both interviews were made in English, extended around one hour, and were conducted via videocalls and personally (Appendix 1 and 2). The information processing includes a summary/diagram that clusters the answers according to topics.

4.3. Meteorological records and Seasonal analysis

The meteorological records from Lahti were obtained from the Finnish Meteorological Institute (n.d.a) website and considered two observation stations: Lahti Laune (LA) (2000-2018) and Lahti Sopenkorpi (SO) (2018-2021); their locations are shown in Figure 18. Each one has information on different periods. They represent a basepoint for understanding the annual climatic conditions in the city. The contrast of seasons and the yearly variations due to climate change demonstrate the relevance of temporary solutions.

Due to the timeframe for the development of this thesis, spring was selected as the season for study. Additionally, it is a transitional period and covers one of the knowledge gaps. A study related to the mean temperature variance from 2000-2020 will determine two critical days (warm and cold) to evaluate in the following steps.

4.4. Identification of Temporary interventions

- Data collection

Two dates were selected for the field survey: May 5th,2021 (monthly market), and May 6th,2021 (daily market). Both included temporary interventions in different ways. The field survey used hand-drawing layouts and pictures. Later the data was processed in Excel and Autocad.

- Classification

Existing interventions were classified into different topics, including colour, material, typology, and activity. Classification is helpful for quantification. Later, typologies will be relevant for the understanding of their microclimate effects.

4.5. Users' behaviour and opinions

- Existing survey

The city of Lahti developed a City Centre Survey (*Kysely Lahden Keskustasta*) between April and May of 2017 (Saari & Niskanen, 2017) to assess citizens' perception and recommendations and recommendations for the area. It used Maptionnaire, an online survey platform that allows to georeferenced the answers. The survey is relevant because Market Square was mentioned as a critical area.

- Online questionnaire

According to the literature review, the user's behaviour is related to outdoor thermal comfort. The count of users at different hours is a standard method (Martinelli et al., 2015; Eliasson et al., 2007). However, considering that the pandemic has reduced visitors, sellers, and events, an online questionnaire was the best option for understanding the subject and enhancing social distancing. The questionnaire was developed with Google Forms and was shared from May

21st to June 25th, 2021. The survey was released in English and Finnish for covering most of the population (Appendix 3).

This step aims to assess the seasonal and hour preferences for visiting Market Square, assuming that the results are linked with outdoor thermal comfort. It also covers the site's perception of environmental elements linked with thermal comfort (wind, sun, and rain). Other aspects include the activities, desires, and opinions of the place. The hour preferences will be used in the simulations.

It follows a convenience sampling based on the availability of participants. A statistically valid sample size of 96 participants was estimated considering Lahti's population size of 119 823, a confidence level of 95% and a margin of error of 10%.

4.6. Traverse study

A traverse study was developed to assess the study area's microclimate. The results will be helpful to understand the air temperature's spatial variation in typical spring conditions and the calibration of the environment model. In total, there were three dates selected for the traverse study (Table 5). The two first are the same as mentioned in the identification of temporary interventions (Section 4.4). Nevertheless, June 18th, 2021was used to confirm the ENVI-met model performance on a sunny day and was just developed at 19:00 (one hour after peak hour).

Table 5. Dates for Meteorological data collection (Own elaboration, 2021)

Date	Events
May 5th 2021	Monthly Market
May 6th, 2021	Daily Market
June 18th, 2021	Daily Market (Stable weather conditions)

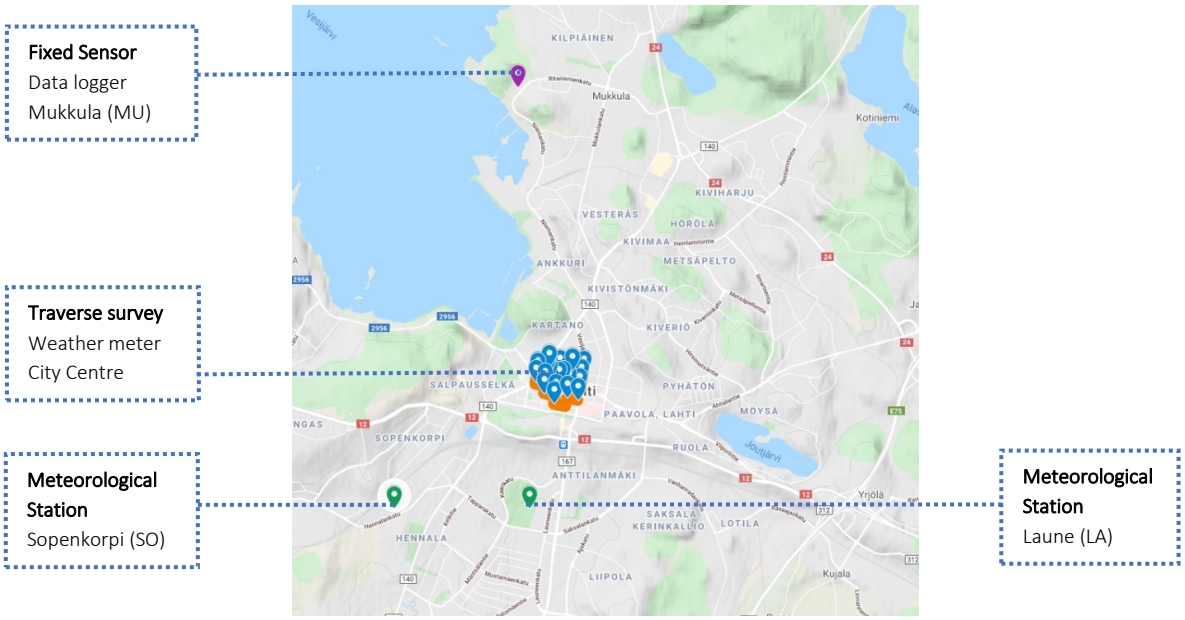


Figure 18. Location of traverse survey, fixed station and meteorological station (Own elaboration, 2021)

The traverse survey presented non-synchronous observation times of the different points; hence it was required to conduct temporal corrections. Data collected from a fixed station and the city's meteorological station Sopenkorpi were used for this purpose (Figure 18).

- Traverse Survey

A walking route of 1.4km was projected to measure 20 points in the Market Square and its surroundings (Figure 19). The survey used a pocket weather meter that reads temperature (±0.5°), relative humidity (±3%), wind speed, wind chill, heat stress index, dew point and time (Kestrel 3000) (Figure 20). The weather meter was held around 2m over the ground level during the survey, and the data was hand-written (Figure 21). The route starts and ends at the same point. It was covered in 1 hour and was taken three times in a day:

- 11:00 Assumed time with higher activity
- 15:00 An hour before the peak temperature of the day
- 21:30 After sunset

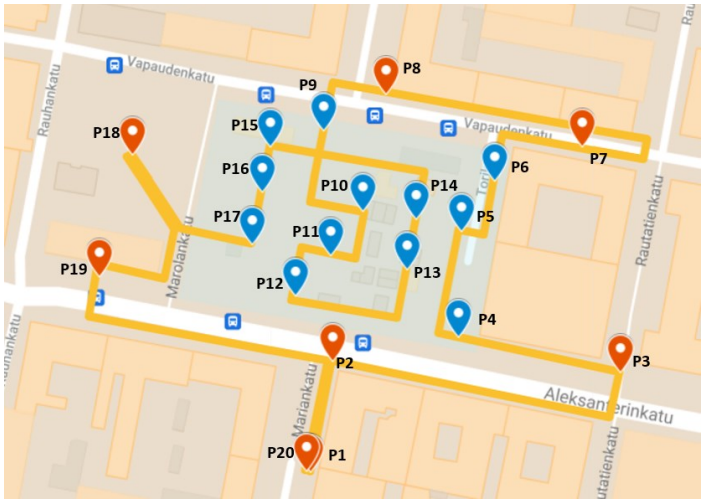


Figure 19. Route for traverse study in Lahti City Centre. (Own elaboration, 2021)

SENSOR	ACCURACY (+/-)	RESOLUTION	SPECIFICATION RANGE
Wind Speed |Air Speed	Larger of 3% of reading, least significant digit or 20 ft/min	0.1 m/s 1 ft/min 0.1 km/h 0.1 mph 0.1 knots 1 B°	0.6 to 40.0 m/s 118 to 7,874 ft/min 2.2 to 144.0 km/h 1.3 to 89.5 mph 1.2 to 77.8 knots 0 to 12 B°
Ambient Temperature	0.9 °F 0.5 °C	0.1 °F 0.1 °C	-20.0 to 158.0 °F -29.0 to 70.0 °C
Relative Humidity	3%RH	0.1 %RH	5 to 95% 25°C non-condensing

Figure 20. Characteristics of Kestrel 3000. (Kestrel, n.d.)

Figure 21. Picture during traverse survey (Own elaboration, 2021).

- Meteorological Station

Sopenkorpi station is in the southern area of Lahti, 2.5km away from Market Square, and the data is recorded every 10 minutes. It presents the following data: cloud amount, precipitation, relative humidity, snow depth, air temperature, dewpoint (Finnish Meteorological Institute, n.d.). Nevertheless, it does not show information about wind direction and wind speed.

- Fixed station

A temperature data logger Tiny Tag TGP-4020 (accuracy: ±0.35°C with 0 to 70°C) (Figure 22) was placed in the outer area of the city in Mukkula neighbourhood, 3.5km away from the Market Square, in a residential area next to a forest. The location was appropriate to obtain records with minimum effects of UHI. It included a thermistor probe (PB-5002-1M5 10K NTC) for more precise results. The tool was at 2m height, and the probe was protected from direct sunshine radiation with a makeshift aluminium foil funnel (Maharoof et al., 2020) (Figure 23). The data intervals were of one minute, optimal for developing the linear regression equations.

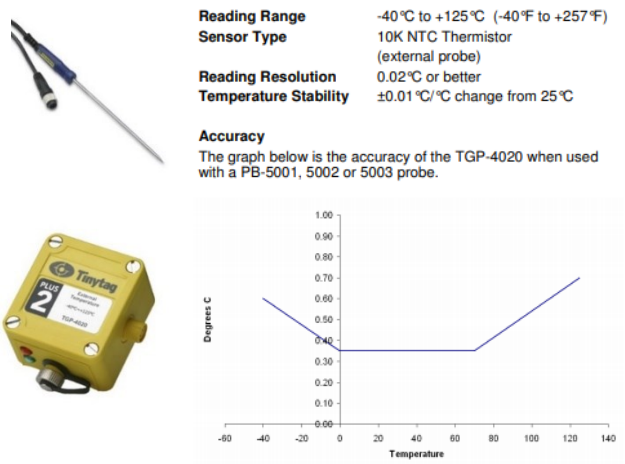


Figure 22. Tiny Tag TGP-4020 specifications (Own elaboration, 2021 images retrieved from geminidataloggers, n.d.)

Figure 23. Fixed Station in Mukkula (Own elaboration, 2021)

- Data correction

The temporal correction had two steps.

  - The development of a linear equation with the fixed station's air temperature data (Mukkula) considered the same time frame as the measurements of the traverse survey were taken.

  - The application of the linear equation in each point's air temperature to derive the data for the same time.

4.7. Initial Simulations

The selected software used for analysing the microclimate and thermal comfort was ENVI-met, version V4.4.5 Summer20. The software is a three-dimensional microclimate model that simulates outdoor environments (Mahroof et al., 2020). Additionally, it is commonly used for the same purposes as the present study, including assessing shelter canopies (Nouri et al., 2018; Cheung & Jim, 2018) and vegetation (Gatto et al., 2020; Duarte, 2015). Nevertheless, some studies expose deficiencies in the programme, e.g., applying a fully covered canopy in a street canyon brought an excessive maximum temperature (Yilmaz et al., 2020).

4.7.1. Model calibration

The calibration of the model required a comparison of the real-world environment with ENVI-met calculations. The daily market was used as the reference case for practical reasons. Therefore, multiple ENVI-met models replicating the built environment were performed for the same day as the traverse survey (May 6th, 2021). Then, results are compared in terms of Potential Air Temperature, and the one presenting the lowest Square Root Mean Error (SRME) value was selected for the case-study simulations. Finally, SRME values were calculated for the monthly market (May 5th, 2021) and the day with stable conditions (June 18th, 2021). SRME is commonly used for validating ENVImet models (Zhang et al., 2018).

4.7.2. Simulations

The model was used in two critical spring days; in each one, three scenarios were calculated. The first scenario is the Market Square without interventions; this will be used as the base case. The second and third scenarios are the daily and monthly markets, respectively, based on the field survey made in May 2021 (see section 4.4). In terms of microclimate, the study includes Potential Air Temperature and Mean Radiant Temperature. The calculation of outdoor thermal comfort used BioMet, a post-processor tool from ENVI-met (Bruse, 2014). Considering the literature review, the index selected for the survey is PET because it is the most used index and has been applied previously in the Nordic region.

4.8. Proposal and validation

The spring's temporary interventions proposal is an output of discussions of comparing the literature review and results. The aim is to improve thermal comfort. It also includes the reflections obtained from the users' behaviour and preferences to develop a project with a human approach and not just numerical. Other essential aspects to consider were the logistics and management of the market for creating viable solutions. Finally, the proposal was validated with a second group of simulations. This phase should guarantee that the new design creates a positive impact in the study area.

Chapter 5: Results

5.1. Interviews

Figure 24 summarises the main topics covered in the interviews made to Timo Arasola and Anne Karvinen-Jussilainen (Appendix 1 and 2). There are three main actors in Market Square: Lahentori, the City of Lahti and the Finnish Heritage Agency. On the one hand, local authorities created a particular scheme for managing the place where Arasola's company, Lahentori, rents the area. The contract has already six years and is unlimited. So, every activity and intervention require the company's approval.

On the other hand, the historical value of the place classifies as a Cultural Heritage site (RKY in Finnish) which the Finnish Heritage Agency regulates. Interventions in the area are limited and require de authorization of the local museum authorities in combination with the city planning.

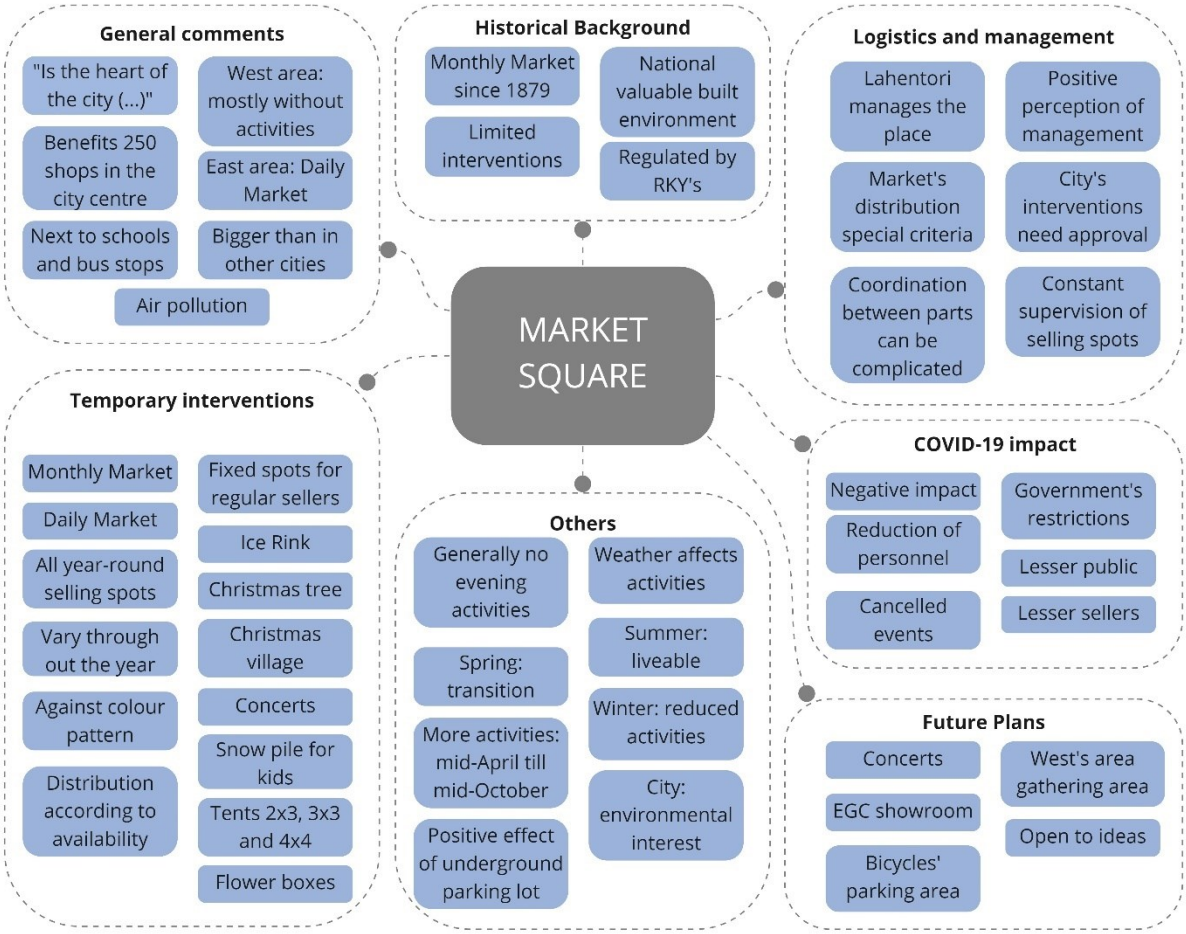


Figure 24. Interview's summary (Own elaboration, 2021)

The general perception of both parties is positive toward the work of each other. Nevertheless, there were issues related to the coordination for the multiple offices connected with the city of Lahti and their different visions. A specific example is the flower boxes that the City of Lahti allocates in the Market Square and other areas of the town during Spring-Summer, but that interferes with the activities of the market. Lahentori looks for a more profitable distribution as a private company, while the City of Lahti aims for the city's liveability.

Temporary elements are mainly commercial and can be divided into monthly and daily markets and year-round selling spots. Other interventions include an ice rink, a Christmas tree and concert stages. The monthly market is the peak of the months in terms of activities. It has been a tradition since 1879 where sellers from around Finland bring their products. Sellers have a variety of booths, but the most common are tents. When asking both parties about homogenising the colours or style of the selling spots, both were against it. For Karvinen, it is not a viable option, and for Arasola, the main thing is that the booths are clean and in good condition. Nevertheless, they were open to other suggestions for the improvement of the market.

Arasola makes the distribution of the market. Regular sellers would prioritise their usual location, and the others would be placed according to their availability and activity. The manager's logistics for the monthly market are well understood (e.g., fried fish sellers cannot be next to clothing booths because of the smell).

Other important factors for the activities in Market Square are the weather and the seasons. The cold winters reduce the attendance and number of sellers. The days start to be longer in spring, and people are more eager to visit the market. On the other hand, summer is the peak season for activities; from mid-April to mid-October, the daily market has more spots. Nevertheless, weather highly influences the attendance of the visitors and restrings the opening hours, especially on windy, rainy, and snowy days. For Arasola, the Finnish culture appreciates summer and spring because sunny and warmer days allow enjoying the outdoor. In contrast, during the other seasons, they stay mainly indoors. Karvinen is concerned about the lack of activities in specific periods.

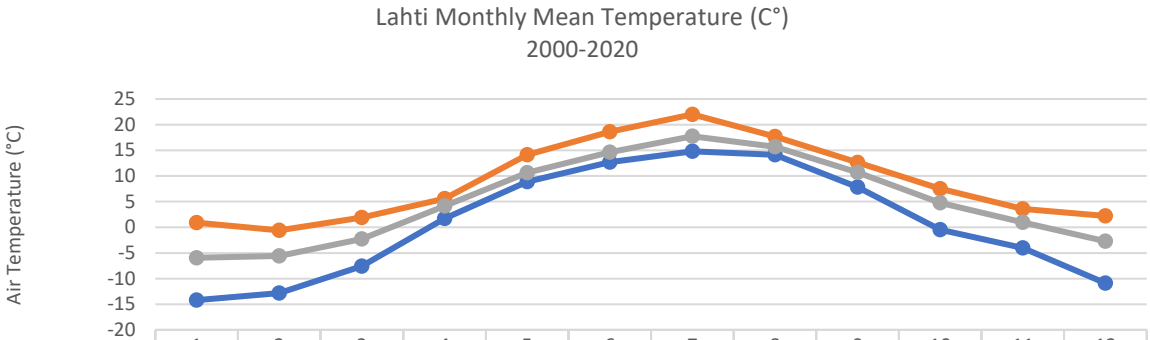
Arasola mentions that opening hours fluctuate. The monthly market is usually open until 3 pm, even though sellers have the chance to remain for longer hours. In summer, the daily market stays open until 8 pm in some cases. However, as mentioned before, this can be changed according to the weather.

Another concern has been COVID-19, which considerably reduced the number of activities, users and consequently shortened the company's profit. Arasola mentioned that the government's restrictions affected the market's distribution, visitors' capacity, and alcohol selling hours. Under current circumstances, planning events has been complicated.

5.2. Annual and Seasonal Meteorological analysis

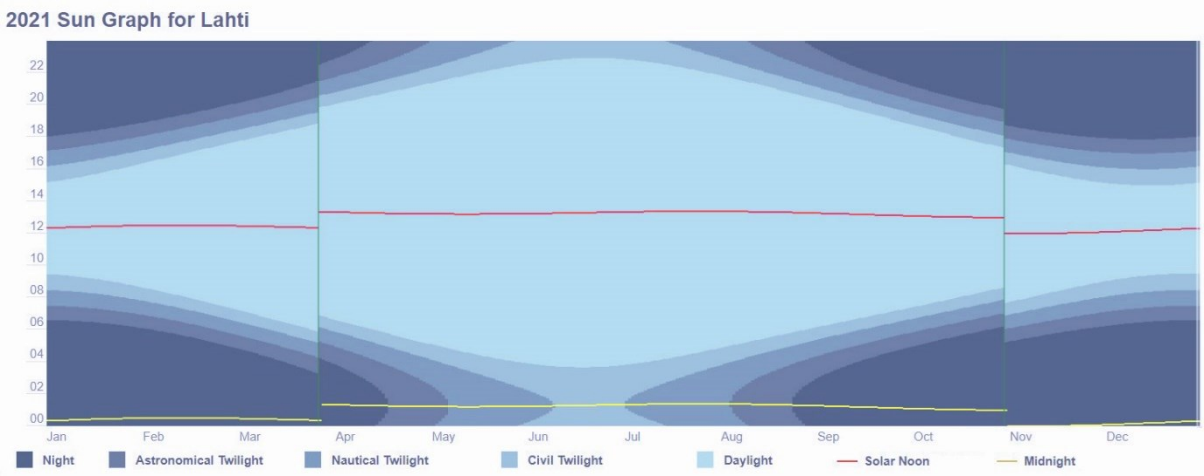
Lahti's weather drastically changes around the year. Graph 1 shows that the maximum mean temperature is 22°C during July while the lowest is -14.2°C during January, considering values since 2000. In terms of seasons, winter and summer are very contrasting, while spring and autumn represent transitional periods in which the temperature changes rapidly compared to other seasons.

In terms of sun hours, winter months present around 6 hours of daylight while summer 18 hours (Graph 2). Sunny days are frequent in May, June and July, and overcast days during November, December and January (Graph 3). Additionally, snow events are present from January-May and September-December, with peaks in winter (Graph 4). Moreover, precipitation days are more frequent in August and December.

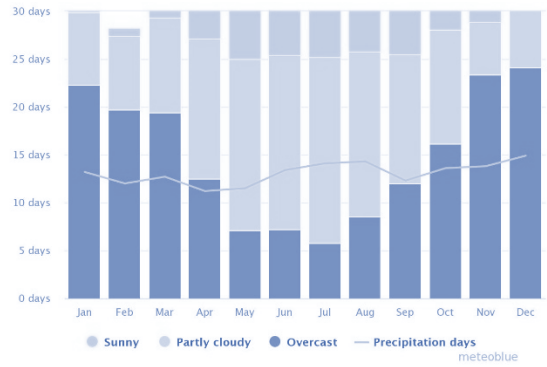


	1 Winter	2 Winter	3 Spring	4 Spring	5 Spring	6 Summer	7 Summer	8 Summer	9 Autumn	10 Autumn	11 Autumn	12 Winter
Min	-14.2	-12.8	-7.6	1.7	8.9	12.7	14.8	14.1	7.8	-0.5	-4	-10.9
Max	0.9	-0.6	1.9	5.6	14.1	18.6	22	17.7	12.6	7.5	3.6	2.2
Average	-5.94	-5.59	-2.26	4.12	10.62	14.61	17.74	15.70	10.68	4.79	0.97	-2.71

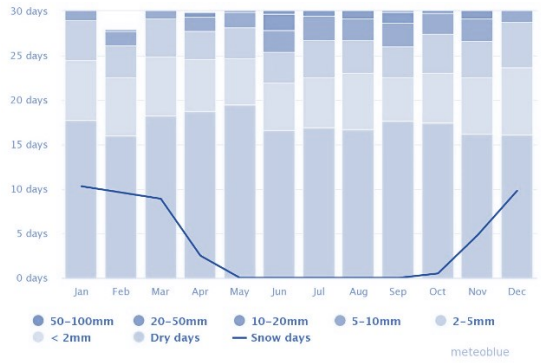
Graph 1. Lahti Monthly Mean Temperature (C°) (Own elaboration, 2021 information retrieved from Finnish Meteorological Institute, n.d.)



Graph 2. Sun Graph for Lahti (timeanddate.com, 2021)

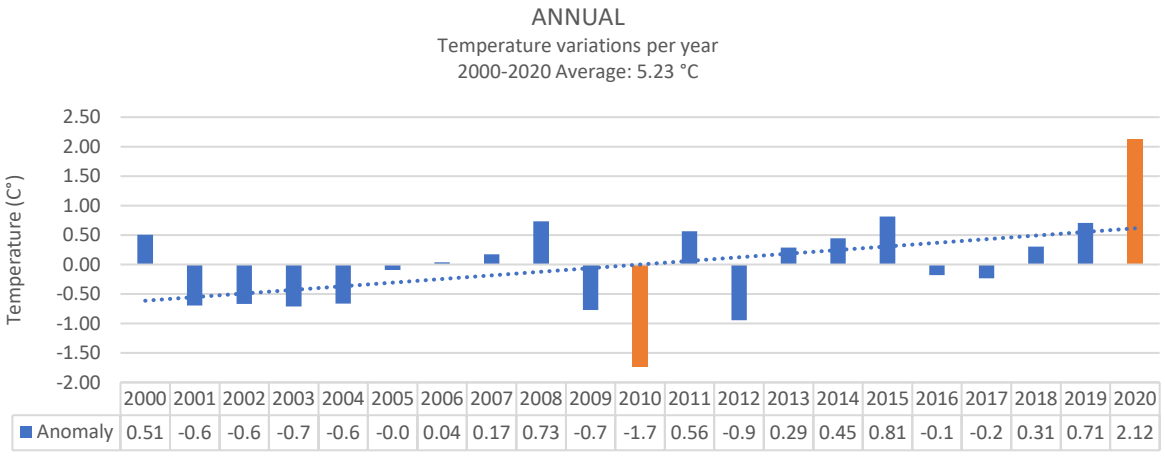


Graph 3. Lahti - Cloudy, sunny, and precipitation days (meteoblue.com, 2021)



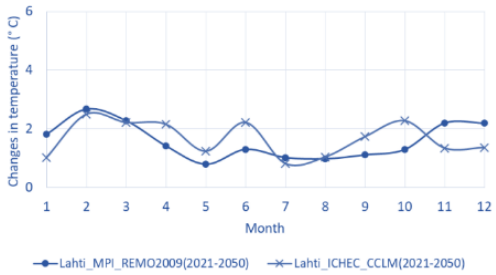
Graph 4. Lahti - Precipitation amounts and snow days (meteoblue.com, 2021)

Graph 5 shows a considerable change in the annual mean temperature variations. The trendline evidences an increase; the last three years had a consistent rise in temperature, with 2020 as the warmest year. Furthermore, a recent report projects an inevitable increase in temperature with two different prediction models (Graph 6 and Graph 7).

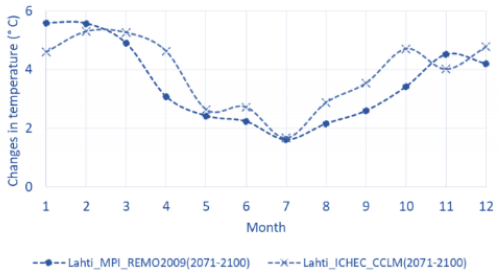


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Anomaly	0.51	-0.6	-0.6	-0.7	-0.6	-0.0	0.04	0.17	0.73	-0.7	-1.7	0.56	-0.9	0.29	0.45	0.81	-0.1	-0.2	0.31	0.71	2.12

Graph 5. Lahti Annual temperature anomaly (Own elaboration, 2021; Finnish Meteorological Institute, n.d.)



Graph 6. Lahti - Prediction for changes in temperature between 1980-2010 and 2021-2050 under REMO2009 and CCLM 8.2 (Johannes & Samrit, 2020)



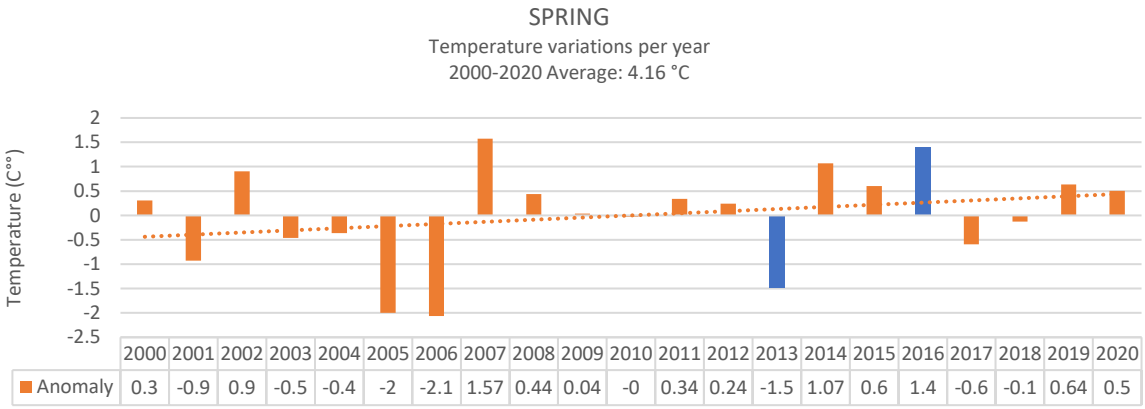
Graph 7. Lahti - Prediction for changes in temperature between 1980-2010 and 2071-2100 under REMO2009 and CCLM 8.2 (Johannes & Samrit, 2020)

Annual variations can be split into seasons for having a more detailed analysis. The Finnish Meteorological Institute (n.d.b) considers that for statistical studies, Spring covers March, April and May (Table 6). The average temperature found between 2000-2020 in this season was 4.16°C. Graph 8 shows the variations in the last years with a rising trendline, similar to the annual analysis. A significant difference is that while 2020 appears as the maximum rise in the

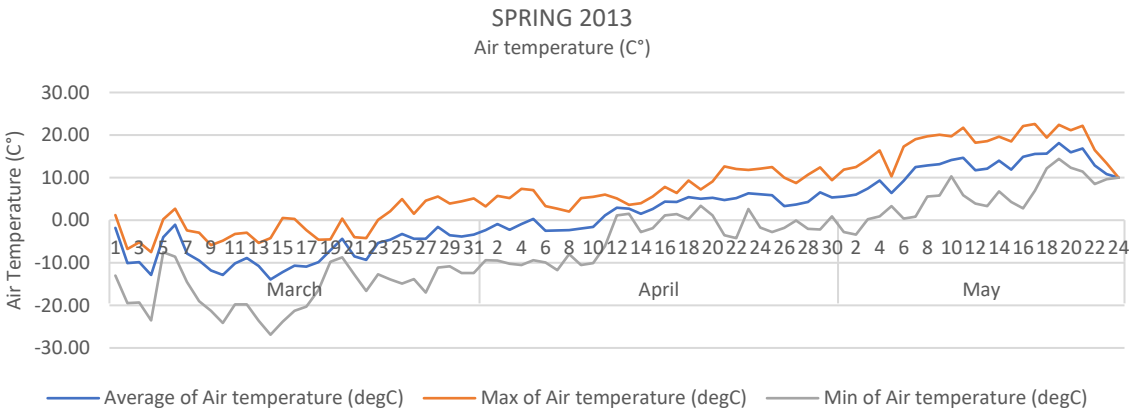
yearly examination, spring 2007 shows the highest increase with 1.57°C. Additionally, the most recent highest variations were found in 2013 (a drop of -1.5°C) and 2016 (a rise of 1.4°C). March 14th, 2013 was the coldest day in that year's season (Figure 9) with an average of -13.92°C. In parallel, May 10th, 2016, represents the warmest spring day (Graph 10) with an average of 16.36 C°. Both days are considered critical for the present study.

Table 6. Seasons' length in Lahti (Own elaboration, 2021. Information retrieved from Finnish Meteorological Institute, n.d.b)

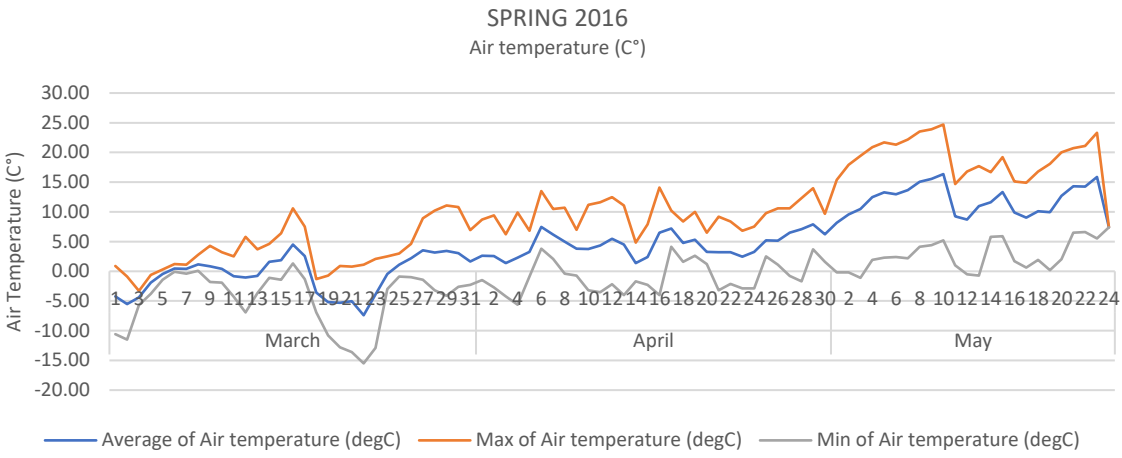
	Months for weather statistics	Criteria for starting Thermal Seasons
Spring	March-May	The average daily temperature rises more permanently above 0 degrees
Summer	June-August	The average daily temperature rises more permanently above +10 degrees
Autumn	September-November	The average daily temperature drops more permanently below +10 degrees
Winter	December-February	The average daily temperature drops more permanently below 0 degrees.



Graph 8. Lahti temperature anomaly per year in Spring (Own elaboration, 2021; Finnish Meteorological Institute, n.d.)



Graph 9. Spring 2013 daily temperature (Own elaboration, 2021; Finnish Meteorological Institute, n.d.a)



Graph 10. Spring 2016 daily temperature (Own elaboration, 2021; Finnish Meteorological Institute, n.d.a)

5.3. Users' Behaviour and Opinions

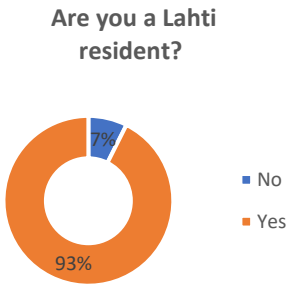
5.3.1. Lahti's City Centre Survey

Lahti's City Centre Survey (Saari & Niskanen, 2017) results expose that 57% of the respondents go several times a week to the city centre. Opinions regarding Market Square were divided and contradictory because it was classified as unpleasant, cosy, and beautiful (Figure 25). The survey also exposed the desire to implement benches, public art, plants, trash bins and bike racks on the site.

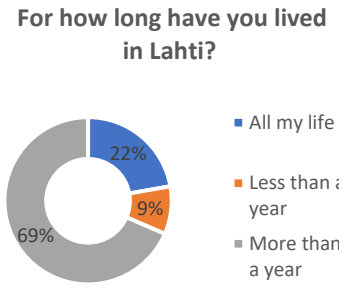
Figure 25. (a) Heat map of unpleasant places, (b) Heat map of Cosy places, (c) Heat map of beautiful places (Saari & Niskanen, 2017).

5.3.2. Online Questionnaire

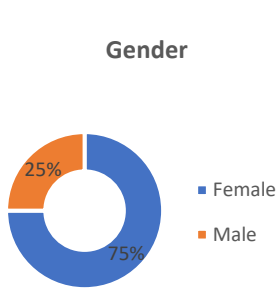
The demographic characteristics of the online survey developed for the present study are shown in Graph 11 to Graph 16. Respondents were mainly Lahti residents (93%); 69% for more than a year, 22% for all their lives and 9% for less than a year. In terms of gender, 75% were women and the rest male. More than half of the participants were in the 25-39 age group (51%), followed by 40-60 (31%). 18-24 had the lowest participation (6%) next to the eldest population (12%). Additionally, the majority lived 1-3 km away from the city centre (36%), followed by 3-5 km (22%), and the city centre's neighbours (17%).



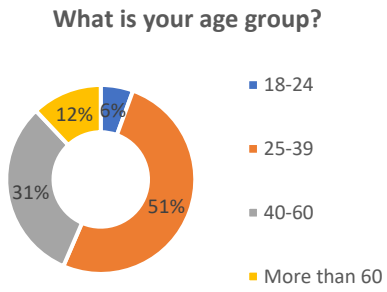
Graph 11. Online questionnaire - "Are you a Lahti resident?" (Own elaboration, 2021).



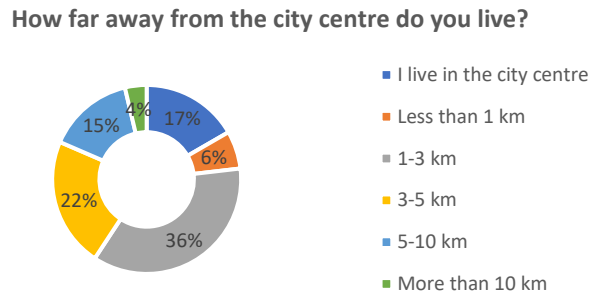
Graph 12. Online questionnaire - "How long have you lived in Lahti?" (Own elaboration, 2021).



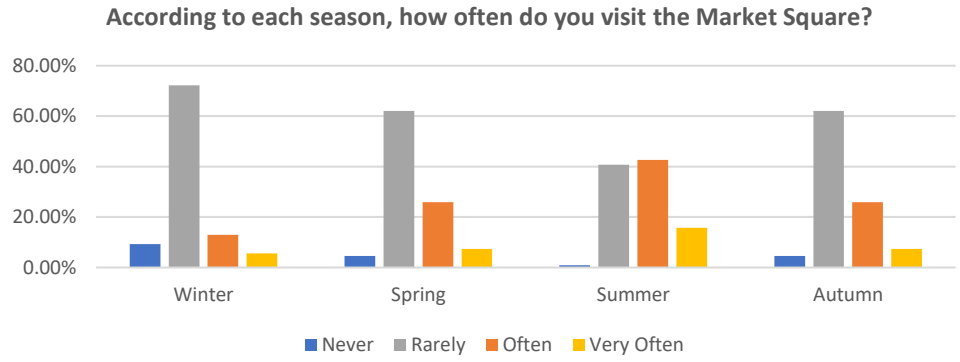
Graph 13. Online questionnaire- Gender (Own elaboration, 2021).



Graph 14. Online questionnaire - "What is your age group?" (Own elaboration, 2021).



Graph 15. Online questionnaire - "How far away from the city centre do you live?" (Own elaboration, 2021).

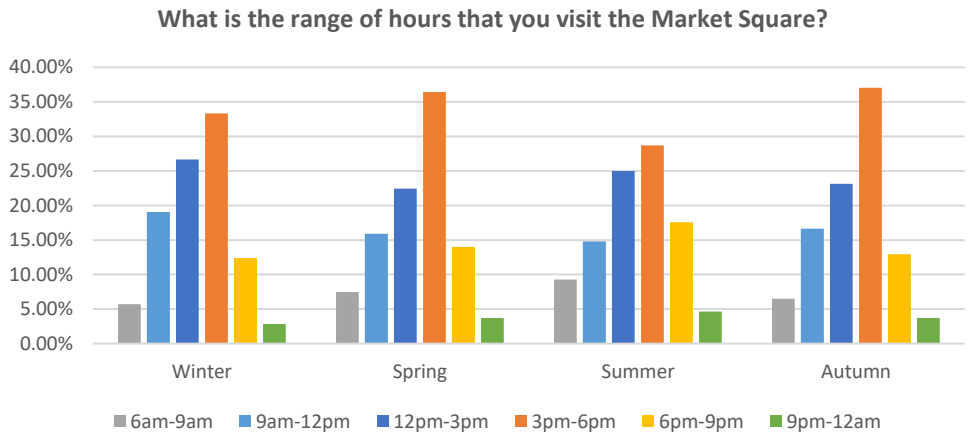


Graph 16. Online questionnaire "How often do you visit the Market Square?" (Own elaboration, 2021).

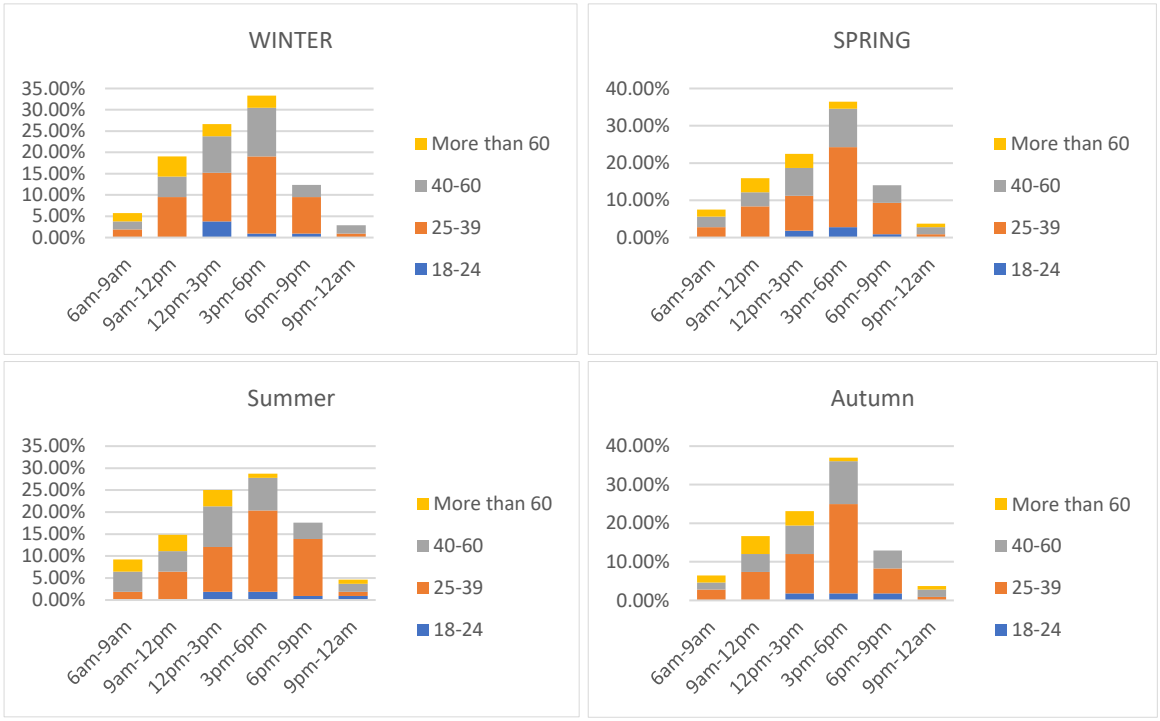
Questions linked with different seasons showed a variation of the users' behaviour. Overall, winter and summer are the most contrasting seasons regarding users' behaviour, while spring and autumn show similarities.

Graph 16 reveals that seasonality affects their visits to the study area. Most respondents "rarely" visited the market during winter (72.0%), spring (62.0%) and autumn (62.0%). In summer, the main answer was "often" (42.6%), closely followed by "rarely" (40.7%). On the other hand, "very often" was not a popular answer in any season but had a peak in summer (15.7%) and a reduction in winter (5.6%). Finally, in summer, the answer "never" was close to zero, which means most people visit the study area. In all the seasons the population that mainly refers to "very often" visits are in the over 60 years age group and living in the city centre.

Graph 17 indicates that 3pm-6pm is the preferred time to visit the Market Square in all seasons, followed by 12pm-3pm. On the other hand, 9pm-12am is the most unpopular time, followed by 6am-9am. Respondents over 60 years old prefer early hours, especially 9am-12pm, while adults of 40-60 vary between 12pm-3pm and 3pm-6pm (Graph 18). The group aged 25-39 years old had a constant inclination to 3pm-6pm, coinciding possibly with the ending of working hours. Simulations will use hours between 12pm-6pm, considering the most popular answers for spring.



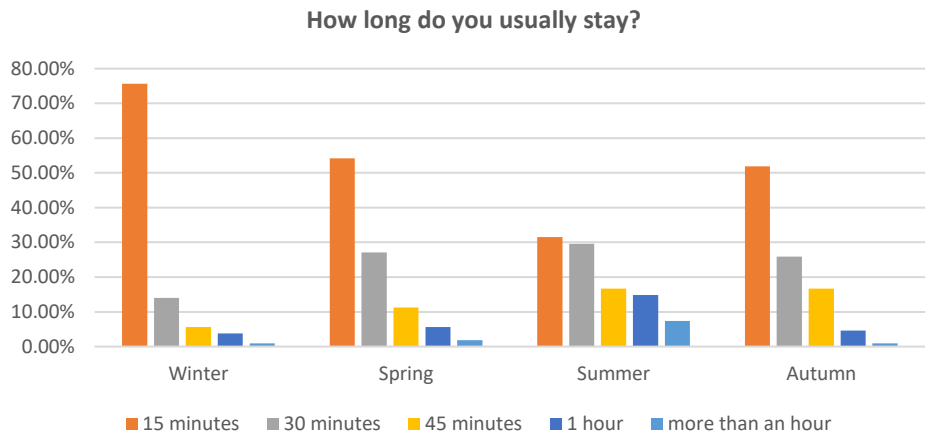
Graph 17. Online questionnaire "What is the range of hours that you visit the Market Square?" (Own elaboration, 2021).



Graph 18. Online questionnaire "What is the range of hours you visit the Market Square?" by age groups (Own elaboration, 2021).

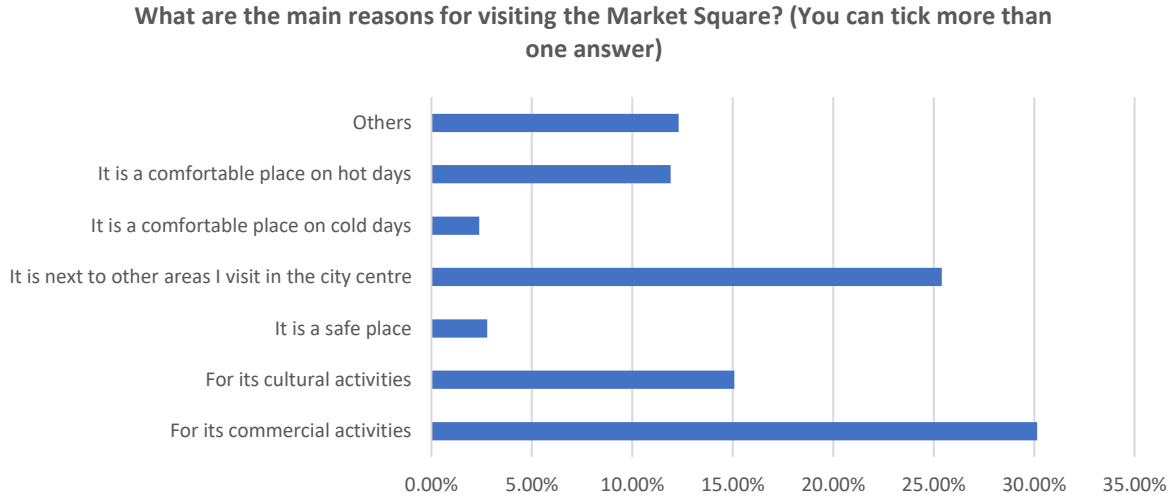
Users stay in the Market Square primarily for 15 minutes in all the seasons, with the highest incidence in winter (75.7%), followed by spring (54.2%) and autumn (51.9%), and finally

summer (31.5%) (Graph 19). Nevertheless, people increase their time stay time throughout the year.



Graph 19. Online questionnaire "How long do you usually stay?" (Own elaboration, 2021).

The main reasons for visiting the study area is for its commercial activities (30.2%), and because it is next to other sites they go in the city centre (25.4%) (Graph 20). In a lower proportion, people indicated their visits corresponded to cultural activities (15.1%). Regarding weather conditions, 11.9% mentioned that they considered the Market Square a comfortable place during hot days, while just 2.4% indicated it is comfortable for cold days. Other reasons included the bus stops, indoors coffee shops, monthly market, local products and summer terraces.

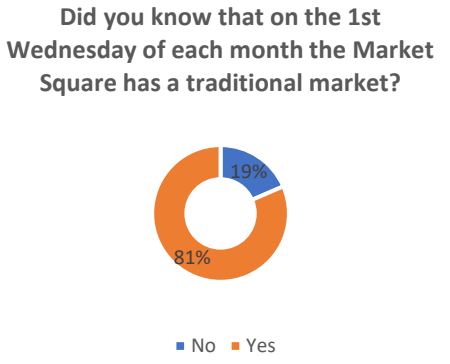


Graph 20. Online questionnaire "What are the main reasons for visiting the Market Square?" (Own elaboration, 2021).

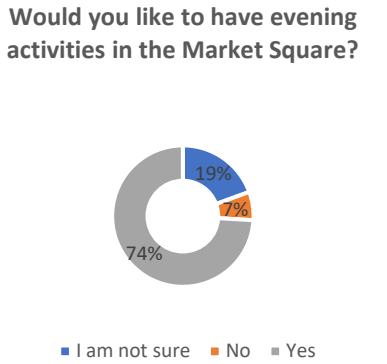
Additionally, 19.0% of the respondents did not know about the monthly market tradition (Graph 21). Most of the people answered positively to the possibility of implementing evening activities, especially in the 25-39 age group and residents living less than 3km or in the city centre (Graph 22). The most voted evening activity was cultural events (30.4%), followed by coffee shops (23.1%) and food vendors (20.7%) (Graph 23). Answers outside the proposed list

included recreative activities, e.g. dancing, games, sports and concerts. Another group of people suggested the implementation of plants.

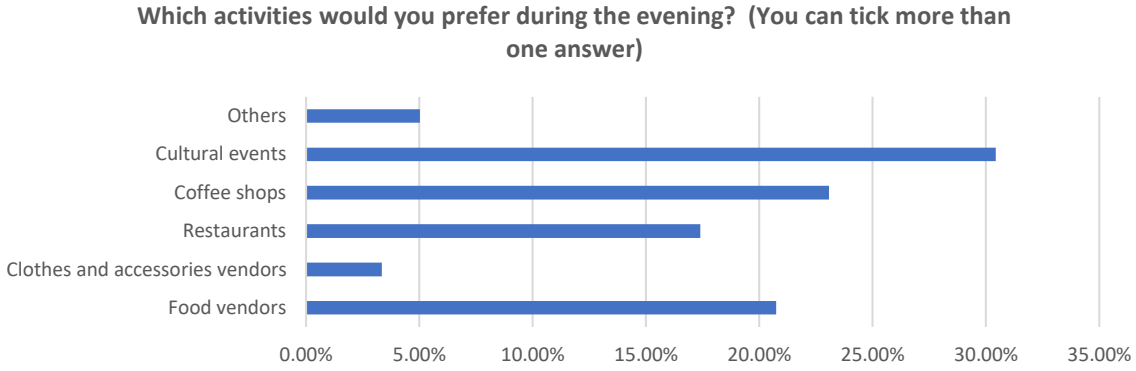
Three questions were related to shading (Graph 24), wind protection (Graph 25) and rain protection (Graph 26) to explore possible opportunities to improve thermal comfort. Users answered that they do not find enough of these elements nowadays in the study area during critical days.



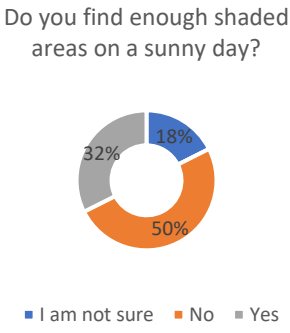
Graph 21. Online questionnaire – "Did you know that on the 1st Wednesday of each month the Market Square has a traditional market?" (Own elaboration, 2021).



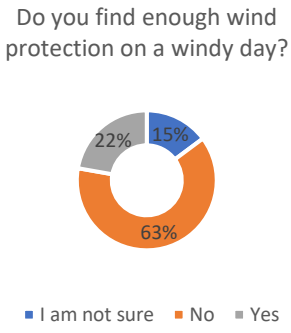
Graph 22. Online questionnaire – "Would you like to have evening activities in the Market Square?" (Own elaboration, 2021).



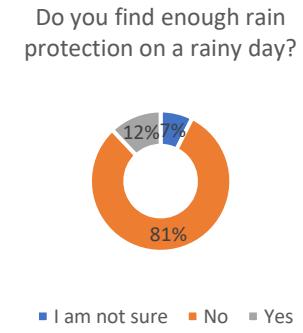
Graph 23. Online questionnaire – "Which activities would you prefer during the evening?" (Own elaboration, 2021).



Graph 24.Online questionnaire – Shaded areas (Own elaboration, 2021).



Graph 25. Online questionnaire – wind protection (Own elaboration, 2021).



Graph 26. Online questionnaire – rain protection (Own elaboration, 2021).

5.4. Identification of temporary elements

Site surveys made in May's Monthly Market 2021 (May 5th) and daily market (May 6th) demonstrate the dynamic characteristic of the study area. Despite just one day apart, the occupied area of the available space of the monthly market was 25% with 97 elements; in contrast, the daily market used 12% with 20 items (Graph 27). Figure 26 to Figure 29 express the layouts and characteristics of both days. It is possible to identify a higher density in the east area in both cases. The west side is occupied during the monthly event. In the daily case, the west and the centre were empty. Additionally, the distribution in both cases respects orthogonal paths, and temporary interventions' size generally matches the floor grid (4x4m). There is a particular alignment of temporary elements next to Aleksanterinkatu Street during the monthly market for taking advantage of the pedestrians' flow.

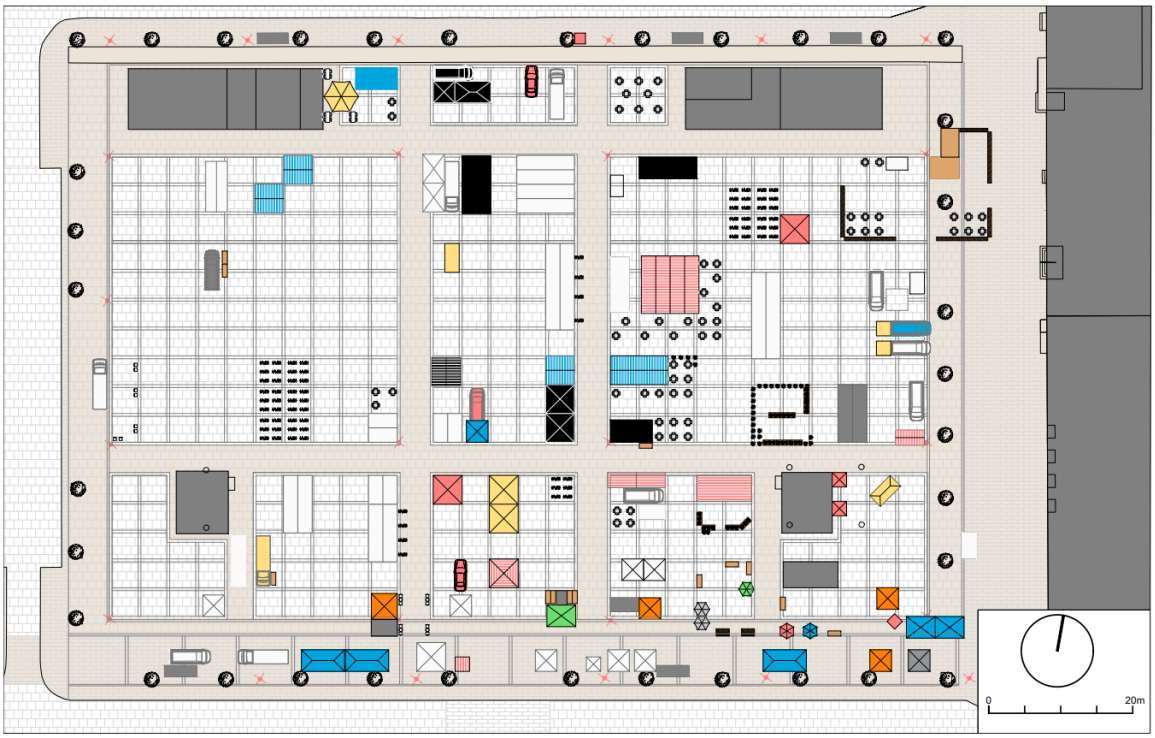


Figure 26. Monthly Market's Layout - May 2021(Own elaboration, 2021)

Figure 27. Panoramic photo of Monthly market (Own elaboration, 2021)

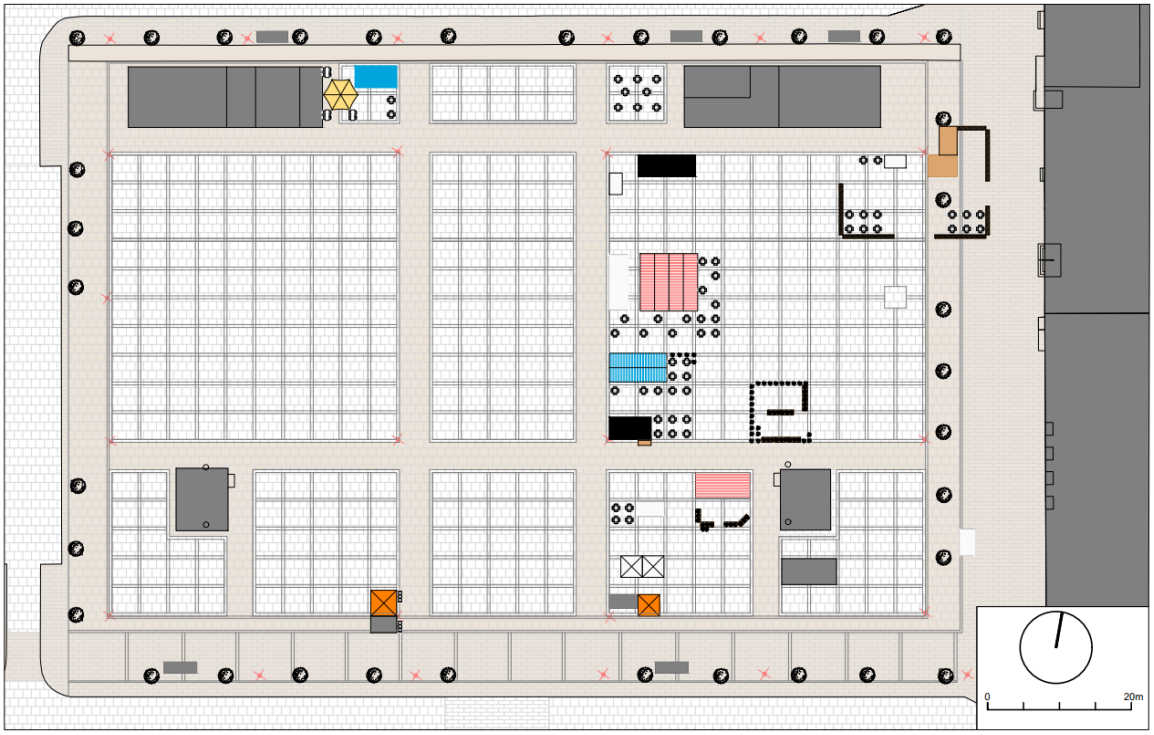
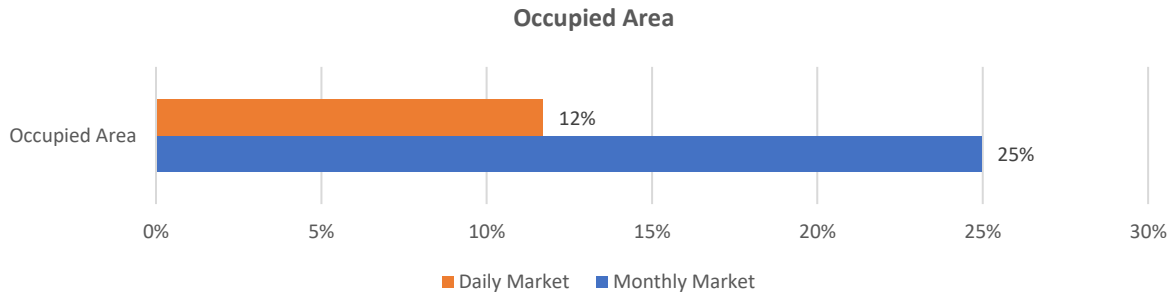


Figure 28. Daily Market's Layout - May 2021 (Own elaboration, 2021).

Figure 29. Panoramic photo of Daily Market (Own elaboration, 2021).



Graph 27. Occupied Area (Own elaboration, 2021)

The temporary elements were classified into six groups, as shown in Figure 30. During the Monthly Market, the main typology were the tents representing more than half of the elements (52). Vehicles and Modules had a similar count (13), followed by Tables (8). In the daily market, the main typologies are the Modules (11), followed by the tents (8). It is essential to

point out that some of these typologies can transform. However, the classification considers the observed characteristics during the survey, e.g., free display types have the structures to allocate a sun sail in case needed.

All the detected activities were commercial (Graph 29). On both days, the most popular activity was the selling of prepared food and food products. The second main activity in the monthly market was selling clothing and accessories, but it does not happen daily. On the other hand, selling flowers is the second main activity during the daily case.

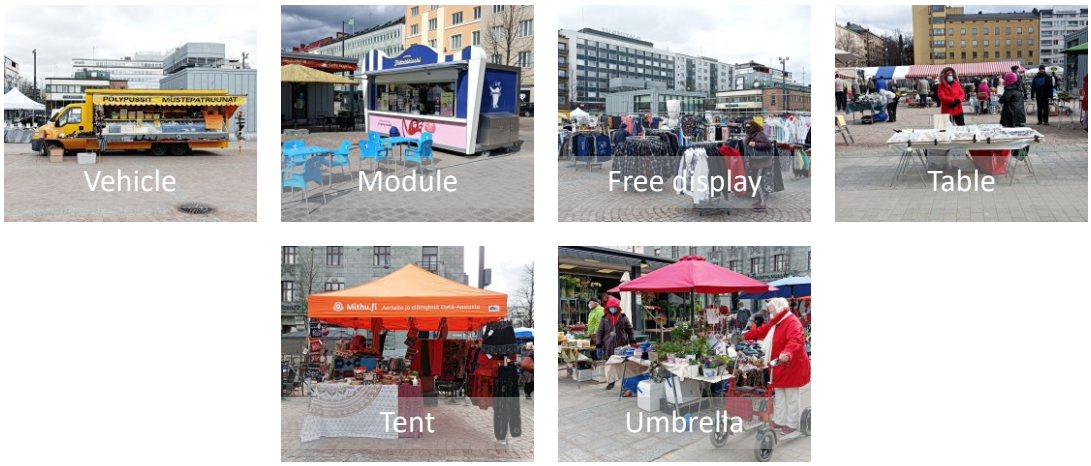
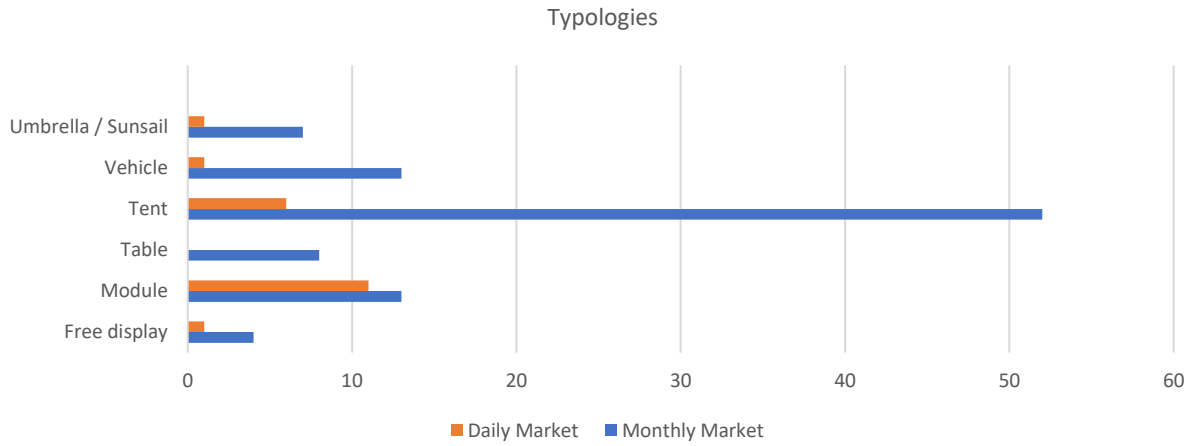
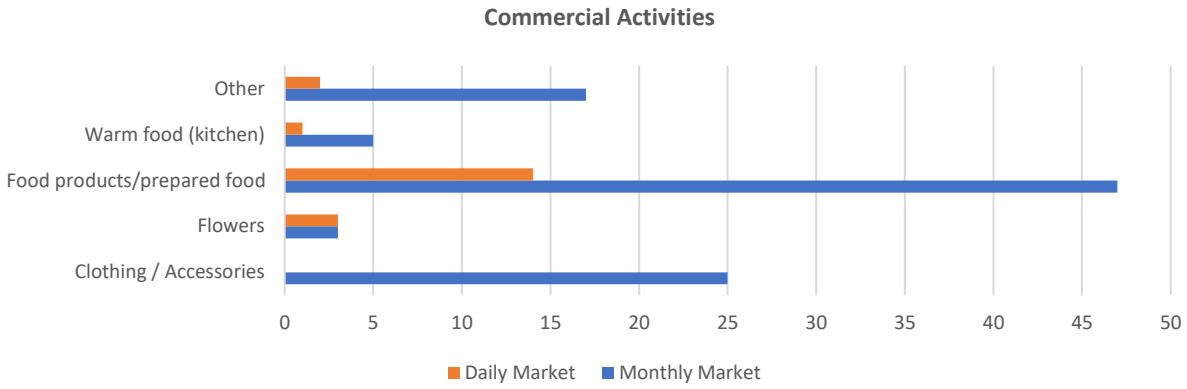


Figure 30. Temporary interventions' typologies (Own elaboration, 2021)

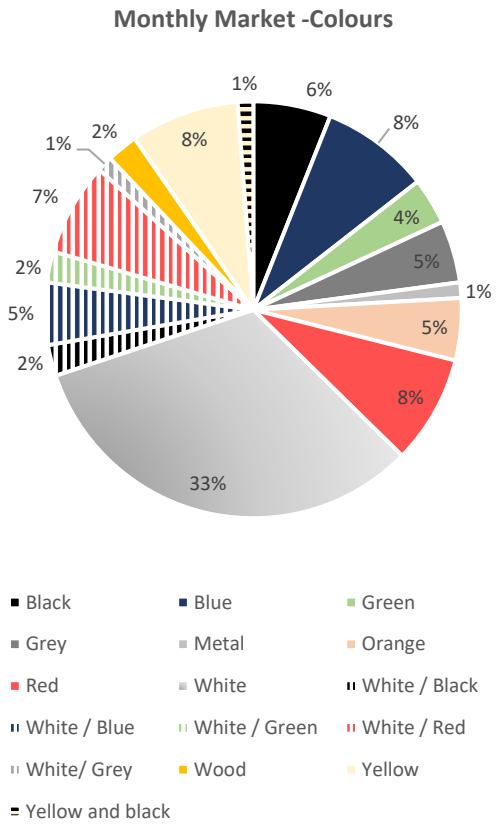


Graph 28. Typologies count (Own elaboration, 2021)

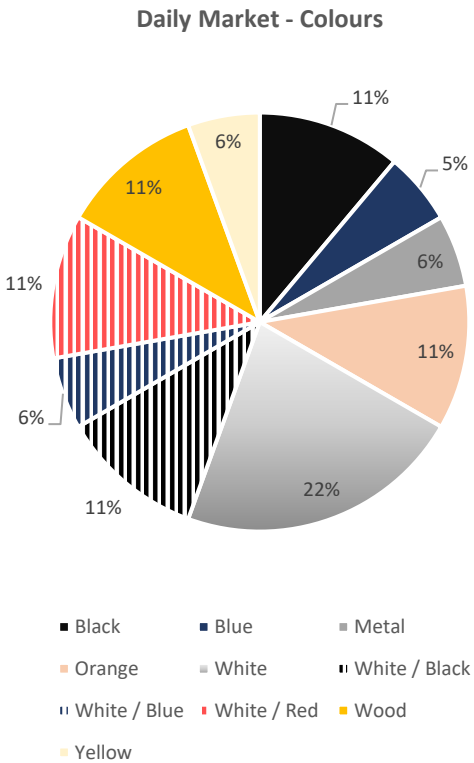


Graph 29. Commercial activities count (Own elaboration, 2021)

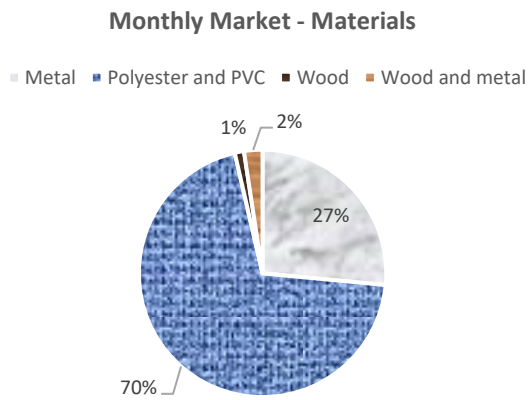
Both days show various colours in the temporary elements, but white is substantially the most common (Graph 30 and Graph 31). Regarding the materials (Graph 32 and Graph 33), Polyester & PVC represented 70% of the interventions during the monthly market, whereas in the daily case was 39%; sources were the tents and umbrellas. On the other hand, metal allocated in vehicles and modules represented 27% of the monthly market and 50% of the daily market. The other identified material was wood and wood with metal. Check Appendix 4, 5 and 6 for further information.



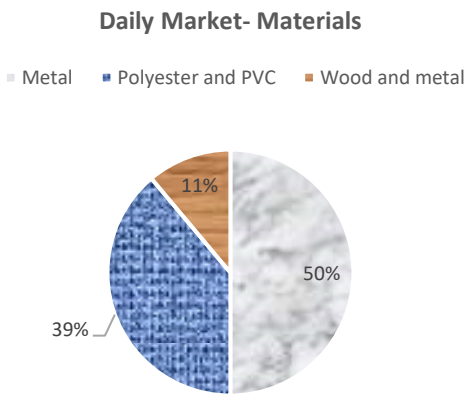
Graph 30. Monthly Market Colours (Own elaboration, 2021).



Graph 31. Daily Market Colours (Own elaboration, 2021).



Graph 32. Monthly Market Materials (Own elaboration, 2021).

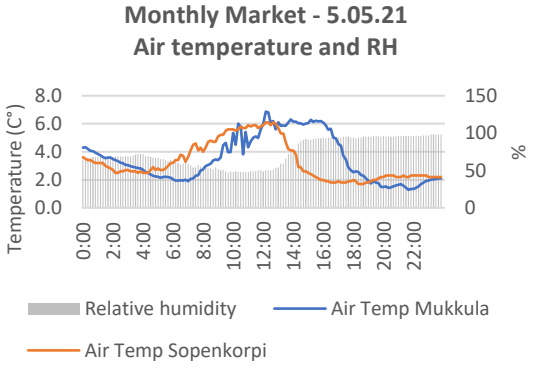


Graph 33. Daily Market Materials (Own elaboration, 2021).

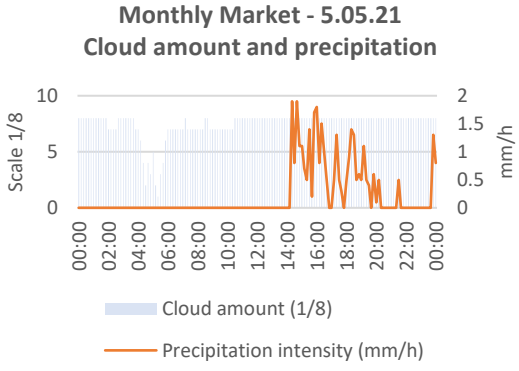
5.5. Traverse survey and ENVI-met model

The weather presented an average RH of 74.30% during May's monthly market, primarily cloudy sky and precipitation starting at 14:20 (Graph 34 & Graph 35); the weather conditions were non-optimal for measurements. Nevertheless, it was essential to continue with this step because of the infrequency of the event. Sopenkorpi station registered the maximum temperature at 12:10 (6.10°C) and the minimum at 18:20 (1.70°C).

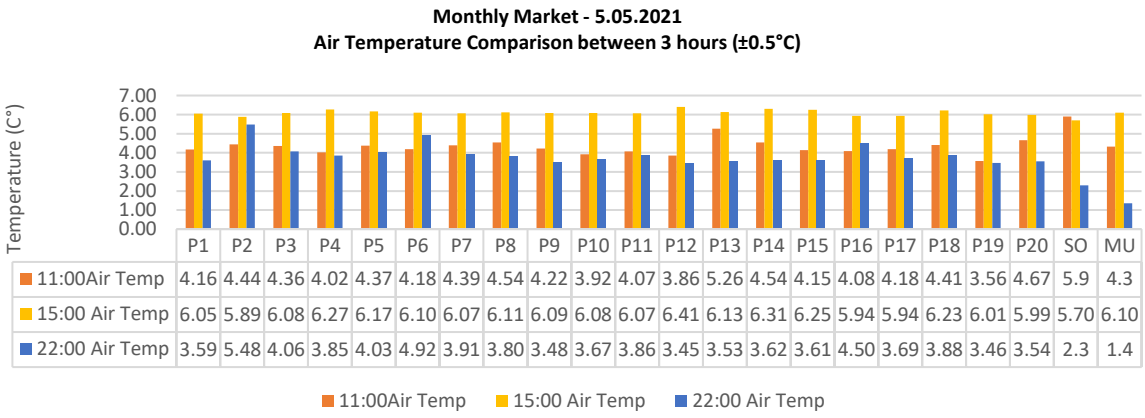
Results showed different temperature variations in the points in each hour (Graph 36). In the morning, the point with higher temperature was P13 (5.26° C), while at night, it corresponded to P2 (5.48 C°). Morning's coldest temperatures were identified in P4, P10, P12 and P19. At 15:00, the air temperature in the area was very similar (5.89°C-6.41°C). Compared to the fixed stations (SO and MU), the city centre's temperature differences were more evident during the night because of UHI.



Graph 34. Air temperature and RH - Monthly Market (Own elaboration, 2021, data retrieved from Finnish Meteorological Institute, n.d.a)

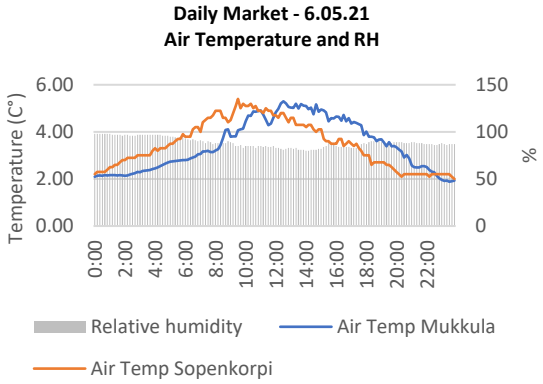


Graph 35. Cloud amount and precipitation- Monthly Market (Own elaboration, 2021, data retrieved from Finnish Meteorological Institute, n.d.a)

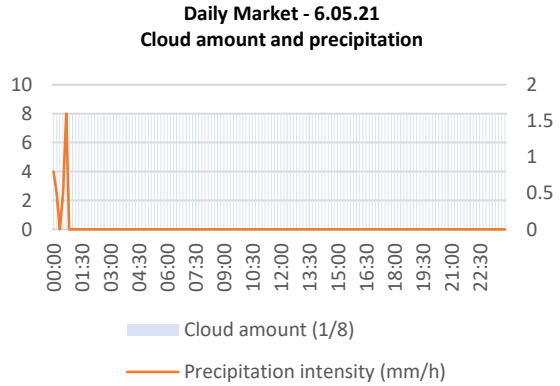


Graph 36. Air Temperature Comparison between 3 hours – Monthly Market (Own elaboration, 2021)

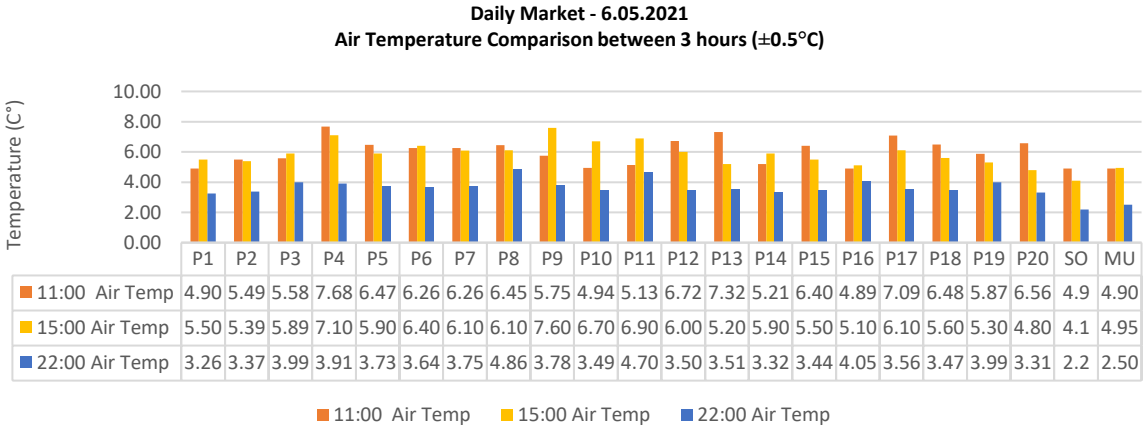
The second traverse study presented similar weather conditions (Graph 37 and Graph 38). The measured points highlight a more significant variation of air temperature than during the monthly market (Graph 39). Additionally, the warmest points during the morning were P4 (7.68 °C) and P13 (7.32°C), in the afternoon P4 (7.10°C) and P9 (7.60°C), and at night P8 (4.86°C) and P11 (4.70°C). The coldest points were difficult to determine because several show similar values considering the accuracy of the tool.



Graph 37. Air Temperature and RH- Daily Market (Own elaboration, 2021 data retrieved from Finnish Meteorological Institute, n.d.a)



Graph 38.Cloud amount and precipitation – Daily Market (Own elaboration, 2021 data retrieved from Finnish Meteorological Institute, n.d.a)



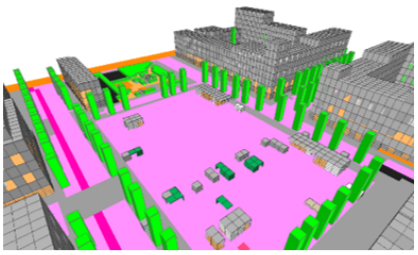
Graph 39. Air Temperature Comparison between 3 hours – Daily Market (Own elaboration, 2021)

Table 7 presents ENVI-met's model details. The validation of the model used the daily market's traverse survey data. Graph 40 and Table 8 confirm that the model has acceptable results. In terms of hours, the highest Root Mean Square Error (RMSE) corresponded to 11:00 (1.05) because of the unstable weather and the temperature rise. P5, P6, and P7 showed the lowest RMSE, while P1 had the highest value.

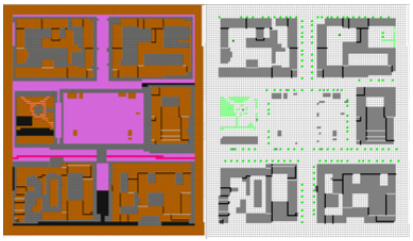
The same procedure was applied on 05.05.2021 (monthly market day) (Appendix 7). 11:00 presented a higher RSME (2.40), but 15:00 and 22:00 showed 0.31 and 0.98, respectively. Overall, the model presented an optimal performance. Nevertheless, RMSE was also calculated with stable weather conditions and a clear sky (18.06.2021), and the values were high (4.31) (Appendix 8). The limitations section discusses the issue.

Table 7. ENVI-met Model and Input details for simulations (Own elaboration, 2021)

ENVI-met Model and Input details for simulations	
Model Dimensions	103x118x20
Cell Size	3x3x3
Method of vertical grid generation	Equidistant, dz of lowest gridbox is split into 5 subcells
Model Rotation out of grid North	10
Nesting Grid	5
Vegetation	T1-Tree 10m very dense leafless base, 00-Grass
Surrounding Buildings' Materials	0100M1, 0100GH, 0100C1
Market Square's Materials	• Temporary interventions: 0000SU (PVC), 000F1 (Wood), 0100ST (Vehicles and modules) • Buildings: 0100AL, 0100M1, 0100GH
Soil	0100ST, 0100SR, 0100BA, 0100PD, 0100GS, 0100TB
Date	6.05.2021
Level	Intermediate, Simple forcing
Wind Speed measured in 10m height (m/s)	1.10 *
Wind Direction (deg)	0.00*
Roughness length at measured site	0.1*
Min and max. T air	Min: 2.20 C°, Max: 5.10 C°
Min and max. RH	Min: 80%, Max 98%

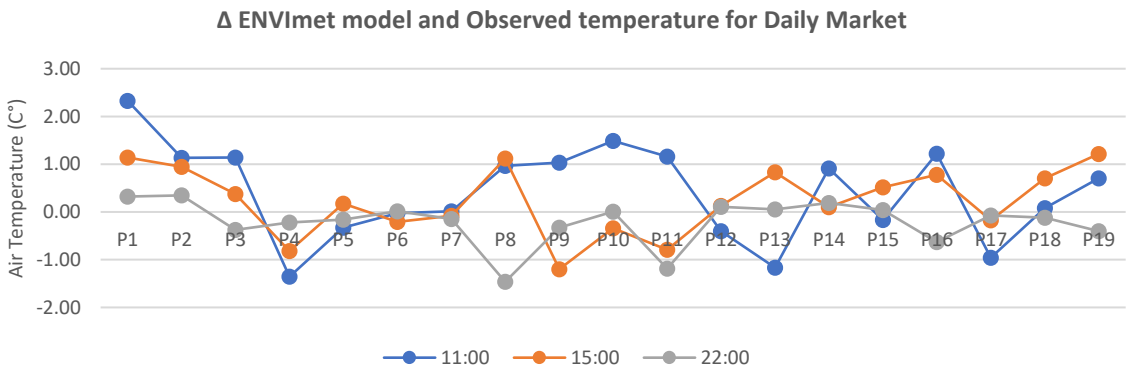


3D view



Soil & Surface **Buildings**

**Data found in Gatto et al., 2020.*



Graph 40. Difference between observed and model temperature (Own elaboration, 2021)

Table 8. Evaluation of measured and simulated temperatures in 6.05.21 (Own elaboration, 2021).

	Observed temperature			Model			Difference			Difference Square			Average	RMSE
	11:00	15:00	22:00	11:00	15:00	22:00	11:00	15:00	22:00	11:00	15:00	22:00		
P1	4.90	5.50	3.26	7.23	6.64	3.58	2.33	1.14	0.32	5.43	1.30	0.10	2.28	1.51
P2	5.49	5.39	3.37	6.63	6.34	3.72	1.14	0.95	0.35	1.29	0.90	0.12	0.77	0.88
P3	5.58	5.89	3.99	6.72	6.27	3.62	1.14	0.38	-0.37	1.29	0.14	0.14	0.52	0.72
P4	7.68	7.10	3.91	6.32	6.28	3.69	-1.36	-0.82	-0.22	1.84	0.66	0.05	0.85	0.92
P5	6.47	5.90	3.73	6.14	6.07	3.57	-0.33	0.17	-0.16	0.11	0.03	0.03	0.05	0.23
P6	6.26	6.40	3.64	6.24	6.19	3.65	-0.02	-0.21	0.01	0.00	0.04	0.00	0.01	0.12
P7	6.26	6.10	3.75	6.27	6.02	3.60	0.01	-0.08	-0.15	0.00	0.01	0.02	0.01	0.10
P8	6.45	6.10	4.86	7.42	7.22	3.40	0.97	1.12	-1.46	0.94	1.26	2.14	1.45	1.20
P9	5.75	7.60	3.78	6.78	6.40	3.45	1.04	-1.20	-0.33	1.07	1.44	0.11	0.87	0.93
P10	4.94	6.70	3.49	6.43	6.36	3.49	1.49	-0.34	0.00	2.22	0.11	0.00	0.78	0.88
P11	5.13	6.90	4.70	6.29	6.11	3.51	1.16	-0.79	-1.19	1.35	0.62	1.40	1.12	1.06
P12	6.72	6.00	3.50	6.32	6.13	3.61	-0.40	0.13	0.11	0.16	0.02	0.01	0.06	0.25
P13	7.32	5.20	3.51	6.15	6.03	3.57	-1.17	0.83	0.06	1.36	0.69	0.00	0.68	0.83
P14	5.21	5.90	3.32	6.12	6.00	3.51	0.91	0.10	0.19	0.83	0.01	0.03	0.29	0.54
P15	6.40	5.50	3.44	6.23	6.02	3.48	-0.17	0.52	0.04	0.03	0.27	0.00	0.10	0.32
P16	4.89	5.10	4.05	6.11	5.88	3.42	1.22	0.78	-0.63	1.48	0.60	0.40	0.83	0.91
P17	7.09	6.10	3.56	6.13	5.93	3.49	-0.96	-0.17	-0.07	0.91	0.03	0.01	0.32	0.56
P18	6.48	5.60	3.47	6.56	6.31	3.35	0.08	0.71	-0.12	0.01	0.50	0.01	0.17	0.42
P19	5.87	5.30	3.99	6.58	6.52	3.59	0.71	1.22	-0.40	0.50	1.48	0.16	0.71	0.84
Average										1.10	0.53	0.25		
Root Mean Square Error (RMSE)										1.05	0.73	0.50		

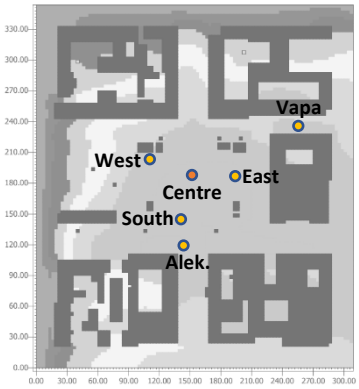


Figure 31. Selected Points Map (Own elaboration, 2021).

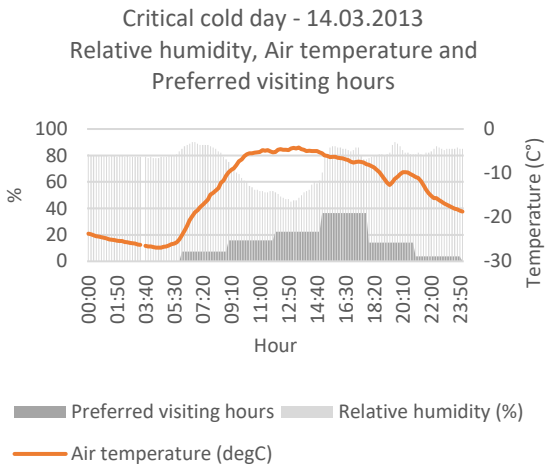
Further analysis requires the comparison between different points inside the Market Square. Five points were selected considering optimal RMSE results and locations (Figure 31). The selection within the Market Square boundaries includes P12 (south), P14 (east) and P15 (west). Finally, the points in the surrounding areas are P2 (Aleksanterinkatu) and P7 (Vapaudenkatu). An additional point is included in the centre for having all the critical areas covered in the analysis.

5.6. Spring's Microclimate and Thermal Comfort Simulations

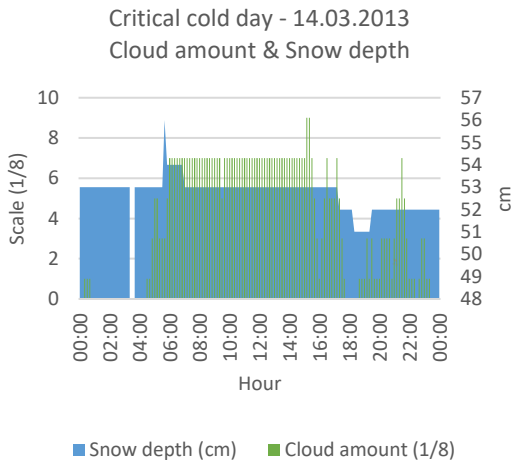
Simulations used the critical warmest and coldest days for spring found in the annual and seasonal temperature analysis. Additionally, the selection of hours for the analysis considered 13:00, 15:00 and 18:00, which were between the preferred visiting hours obtained from the online questionnaire. Three scenarios are compared to obtain results about the microclimatic and thermal comfort changes with the temporary interventions. Additionally, it includes a PET comparison between six reference points mentioned in the previous section.

5.6.1. Critical Cold Day

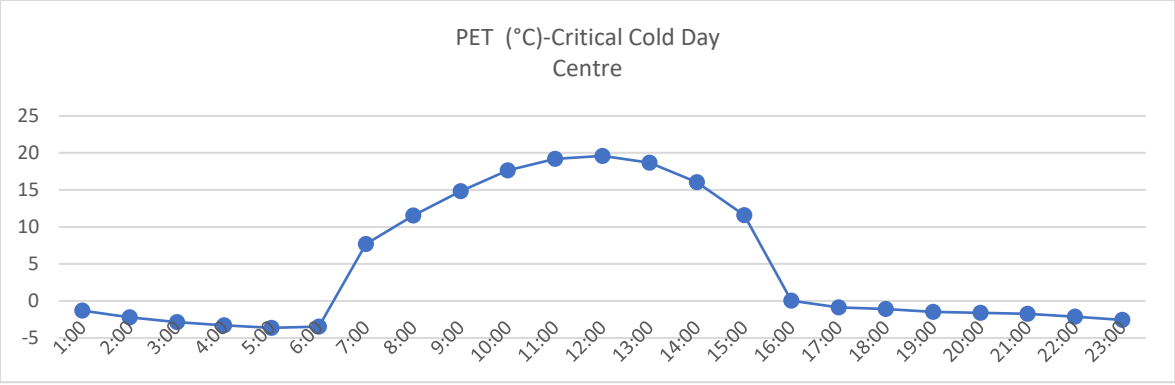
The average Air temperature was -13.95°C, with a maximum of -4.2°C at 13:30 and a minimum of -26.9 °C at 04:20 (Graph 41). The date presented snow and cloudiness (Graph 42). Meanwhile, the average relative humidity was 75.65% (RH max. 90%, RH min 45%). PET evolution in the centre of the plaza has a peak at noon and a minimum value at 05:00 (Graph 43). There is a notorious temperature change at 06:00 and 16:00.



Graph 41. Critical cold day - 14.03.2013 Relative humidity, Air temperature and Preferred visiting hours (Own elaboration, 2021).



Graph 42. Critical cold day - 14.03.2013 Cloud amount & Snow depth (Own elaboration, 2021).

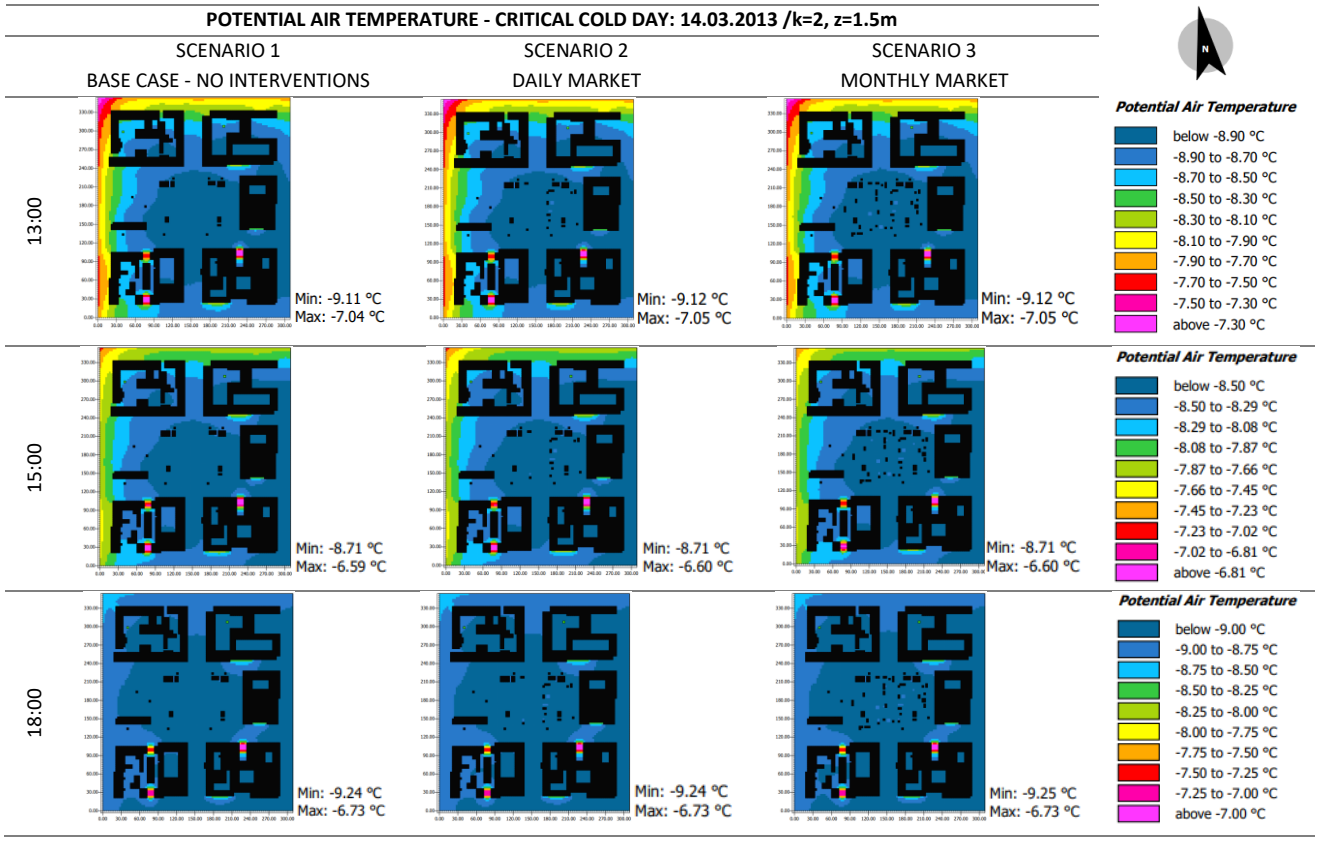


Graph 43. PET in the centre of the Square - Critical Cold Day (Own elaboration, 2021).

Potential Air Temperature (T_{Air})

In all the cases, there is a concentric distribution of T_{Air} being the plaza the centre with lowest values. Temporary elements did not show any significant difference in T_{Air}. Some tents present higher inner temperatures than the open-air areas.

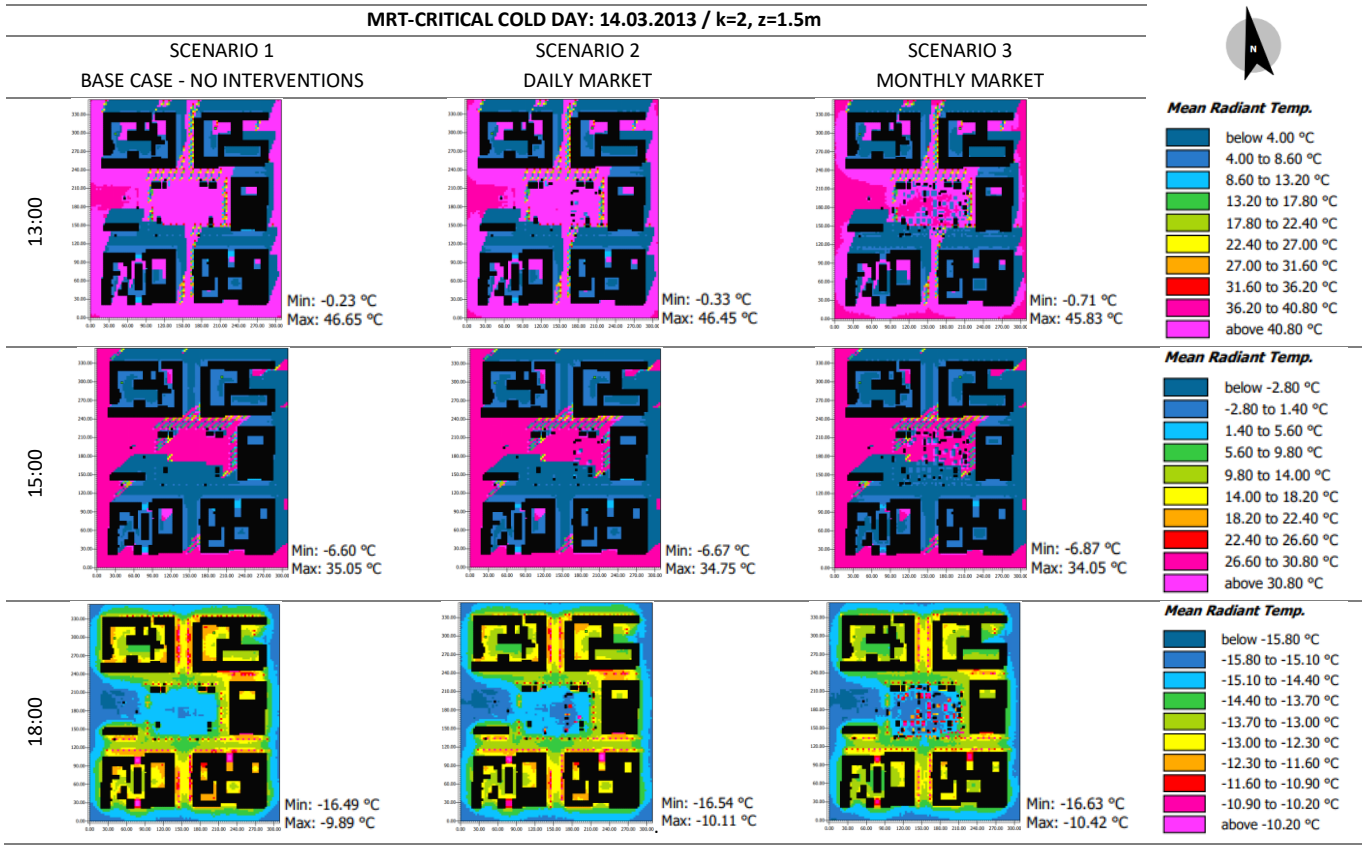
Table 9. Potential Air Temperature - Critical Cold Day (Own elaboration, 2021)



Mean Radiant Temperature (MRT)

There is a contrast in MRT in all the cases. The MRT between the temporary elements reduces at noon and evening. Additionally, it shows lower values beneath the tents than open-air ones at 13:00 and 15:00, but at 18:00, the situation is the opposite. The trees have a warming effect more notorious at 18:00, but the presence of the temporary elements ameliorates it in S3 (east side of the plaza).

Table 10. MRT-Critical Cold Day (Own elaboration, 2021)



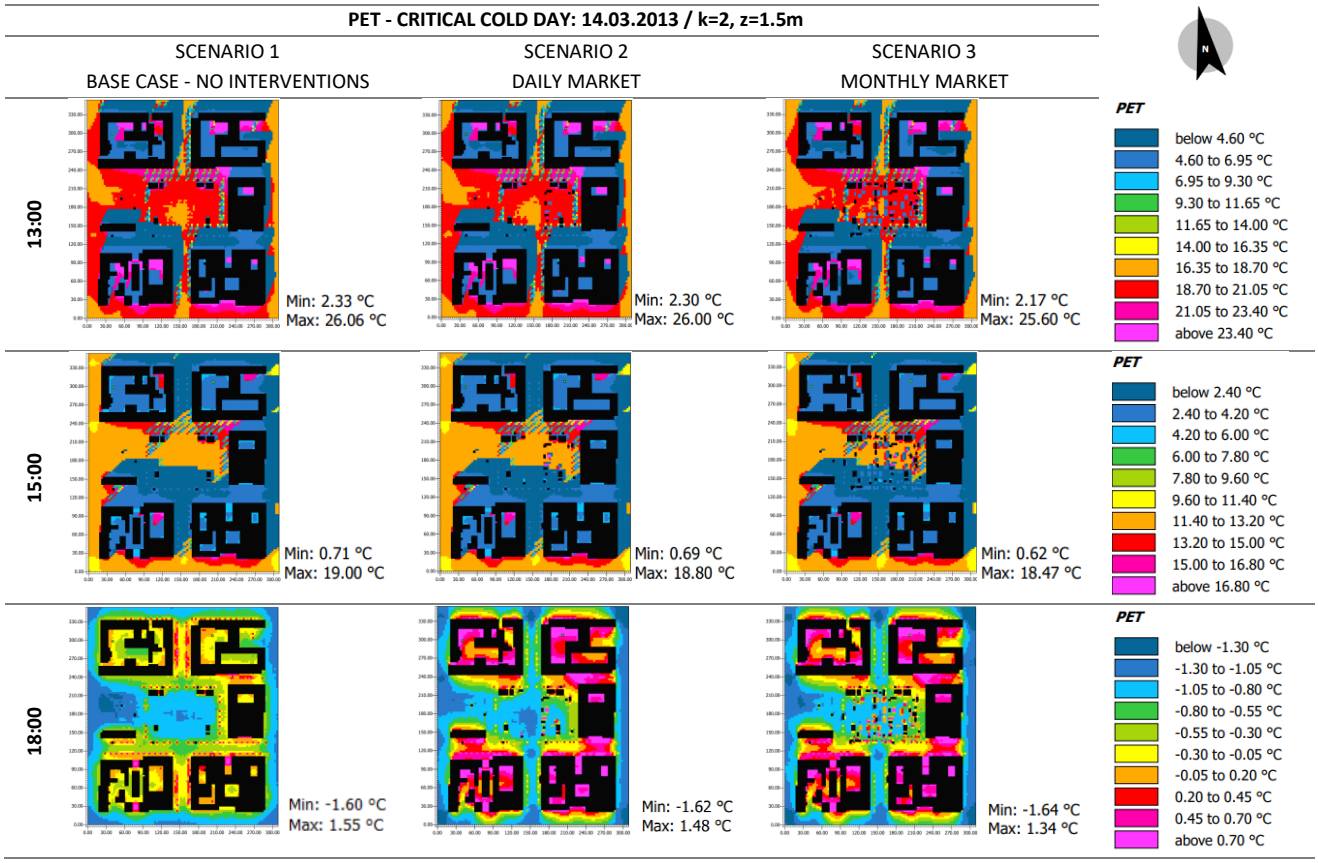
Physiological Equivalent Temperature (PET)

Despite T_{Air} at 13:00 in the plaza is below -8.90°C, PET shows in all scenarios that it is mainly "Comfortable", the following section discussed this result. Nevertheless, the other hours present lower values of PET. At 15:00, the square is divided into "Very cold" and "Slightly Cool" in all scenarios, and at 18:00, it is "Very cold".

The inner area of shelter canopies is colder than the outside at 13:00 and 15:00. However, at 18:00, the situation is the opposite. Also, the perimeter of the elements presents a warming effect, especially at 15:00.

Finally, the trees show an influence in PET. At 13:00, it has a cooling effect, while at 15:00, it presents both effects (cooling/warming) depending on its position., more comments in the discurssion section.

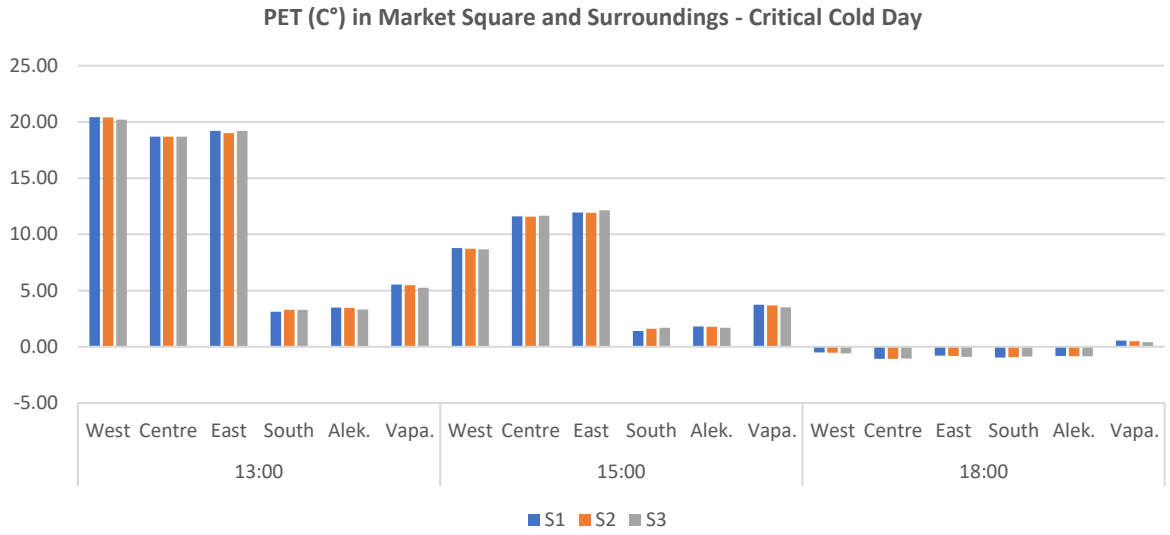
Table 11. PET - Critical Cold Day (Own elaboration, 2021)



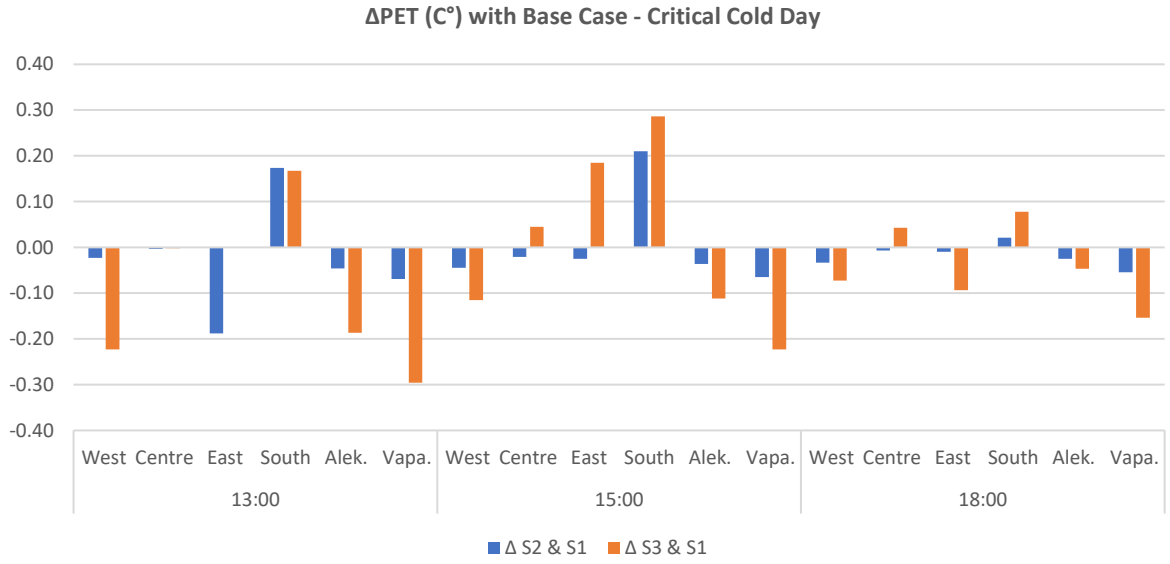
The following graphs describe the changes in six critical points. The plaza's areas showed higher temperatures than the surrounding streets at 13:00 and 15:00, but at 18:00, Vapaudenkatu was the warmest point (Graph 44). At 13:00, the west, centre and east points had the highest PET in all the cases, within "comfortable" values. On the other hand, at 15:00, the east had the maximum temperature, and the south had the minimum. Finally, in the evening, the coldest area was the centre and the warmest in the west.

Graph 45 exposes that the effect of the temporary elements varies. In some cases, the effect of S2 and S3 were contrary. At all hours, S2 shows mostly a cooling effect except in the south. Compared to the base case (Δ), the maximum temperature reduction in S2 was at 13:00 in the east (-0.19°C), and the maximum increase was at 15:00 in the south (0.21°C).

Meanwhile, S3 reveals a persisting cooling influence in the west and the surrounding streets and a warming impact in the south. Its maximum decrease was in Vapaudenkatu at 13:00 (-0.30°C) and the maximum increase in the south at 15:00 (0.29°C). Notice that at 13:00, S3 did not cause any change in the east. Additionally, in the evening, S3 showed a warming effect in the centre, east and south.



Graph 44. PET (C°) in Market Square and Surroundings - Critical Cold Day (Own elaboration, 2021)



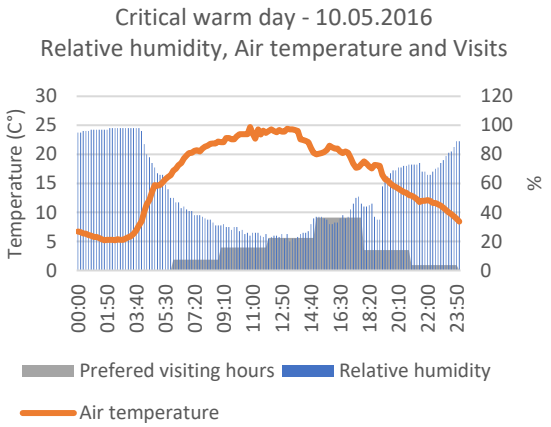
Graph 45. PET difference (C°) – Critical Cold Day (Own elaboration, 2021).

Table 12. Summary of PET effects – Critical Cold Day (Own elaboration, 2021).

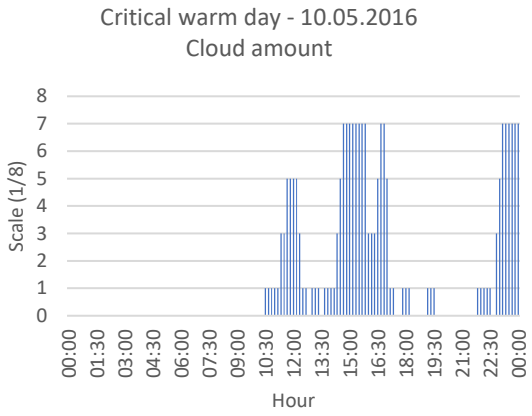
	DAILY MARKET (occupied area: 12%)	***MONTHLY MARKET (occupied area: 25%)***
13:00	Max Positive Δ in South (+0.17°C) (↑) / Max negative Δ in East (-0.19°) (↓)	Positive Δ in South (+0.17°C) (↑) / Max negative Δ in Vapaudenkatu (-0.30°C) (↓)
15:00	Positive Δ in South (+0.21°C) (↑)/ Max negative Δ in Vapaudenkatu (-0.06°C) (↓)	Max Positive Δ in South (+0.29°C) (↑) / Max negative Δ in Vapaudenkatu (-0.22°C) (↓)
18:00	Positive Δ in South (+0.02°C) (↑)/ Max negative Δ in Vapaudenkatu (-0.05°C) (↓)/Negligeable effects.	Max Positive Δ in South (+0.08°C) (↑) / Max negative Δ in Vapaudenkatu (-0.15°C) (↓)

5.6.2. Critical Warm Day

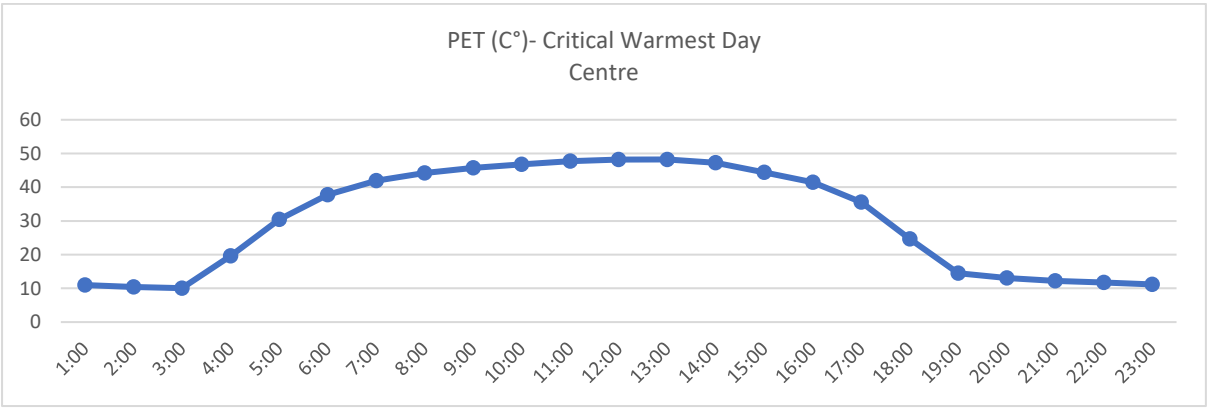
The air temperature had an average of 16.30 °C, a maximum of 24.7 C° at 10:50 and a minimum of 5.2 °C at 01:40, while the average relative humidity was 55% (RH max. 98%, RH min 20%) (Graph 46). The sky was mostly clear but with fluctuating clouds after 10:30 (Graph 47). Meanwhile, the centre shows a PET peak at noon., it has significant variations at 03:00 and 16:00 (Graph 48).



Graph 46. Critical warm day - 10.05.2016 Relative humidity, Air temperature and Visits (Own elaboration, 2021).



Graph 47. Critical warm day - 10.05.2016 Cloud amount (Own elaboration, 2021).



Graph 48. PET in the centre of the Square - Critical Warm Day (Own elaboration, 2021).

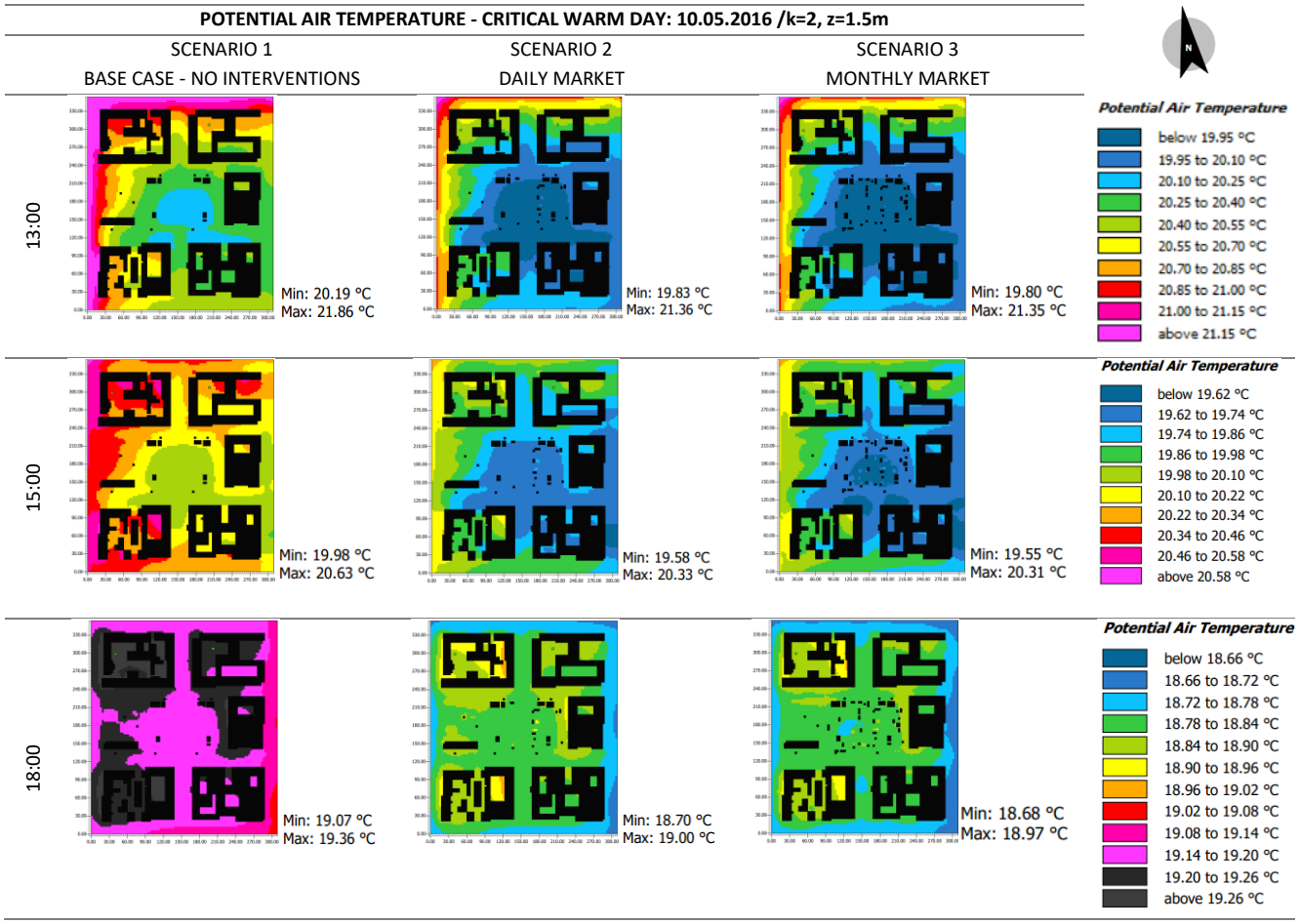
Potential air temperature (T_{Air})

T_{Air} remains concentric. Additionally, by observing maximum and minimum T_{Air}, values are always higher in S1 and lowest in S3. Hence, there is a relation between the occupancy of temporary interventions and the decrease of T_{Air} in the plaza and its surroundings.

Focusing on the temporary elements, at 13:00 the tents of S2 and S3 do not show significant differences of T_{Air} beneath the tents, except for two cases of larger sizes. The situation changes at 15:00 and 18:00, where the footprint of these elements refers to warmer T_{Air} than in the open-air area. Also, the tents' inner temperature is higher in S2 than in S3.

Notice that at 18:00, the situation between the three scenarios is contrasting. S1 presents higher temperatures than S2 and S3. Additionally, the cooling effect in the surrounding buildings show differences in S2 and S3.

Table 13. Potential Air Temperature - Critical Warm Day (Own elaboration, 2021)

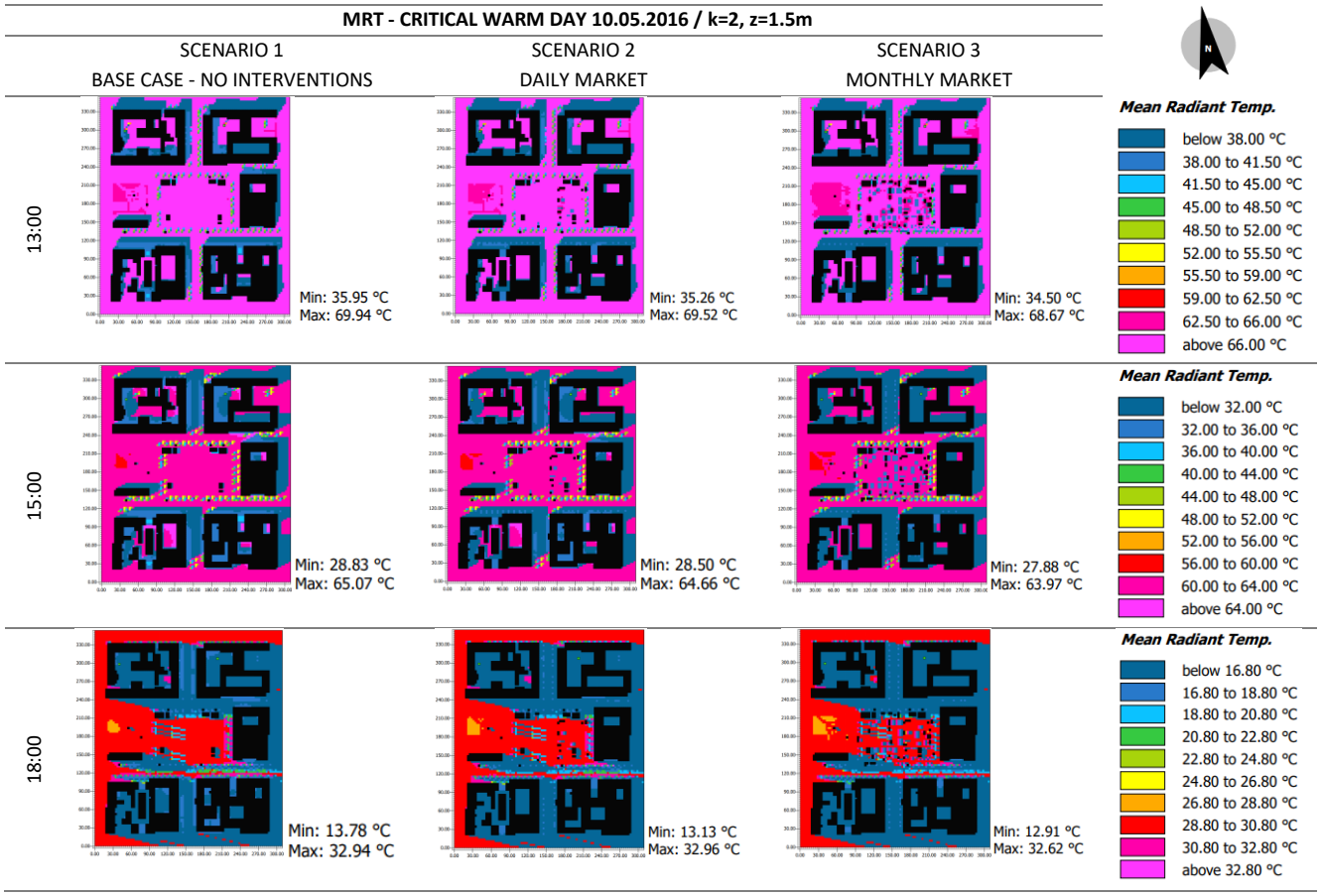


Mean Radiant Temperature (MRT)

The influence of temporary elements is evident in the MRT maps. In S1, at 13:00, the complete plaza was above 66°C, while S2 and S3 showed a mixture of values. There is a notorious increase in the cooling effect in this same hour when having a more densely arranged layout (S2 and S3). At 18:00, S3 show the opposite effect around the elements (MRT rises). S1 and S2 show an increase of MRT around the trees on the right side of the plaza during the evening.

Like T_{Air}, surrounding areas also show a reduction of MRT with the presence of temporary interventions. At 13:00, MRT between these elements has the same temperature category as the grass of the Alatori Plaza and the trees. Also, the vegetation allocated in Mariankatu and Aleksanterinkatu shows a more punctual effect in S2 and S3 than in S1. In all the scenarios at 18:00, the nearby streets show lower values than the middle of the plaza.

Table 14. MRT - Critical Warm Day (Own elaboration, 2021)

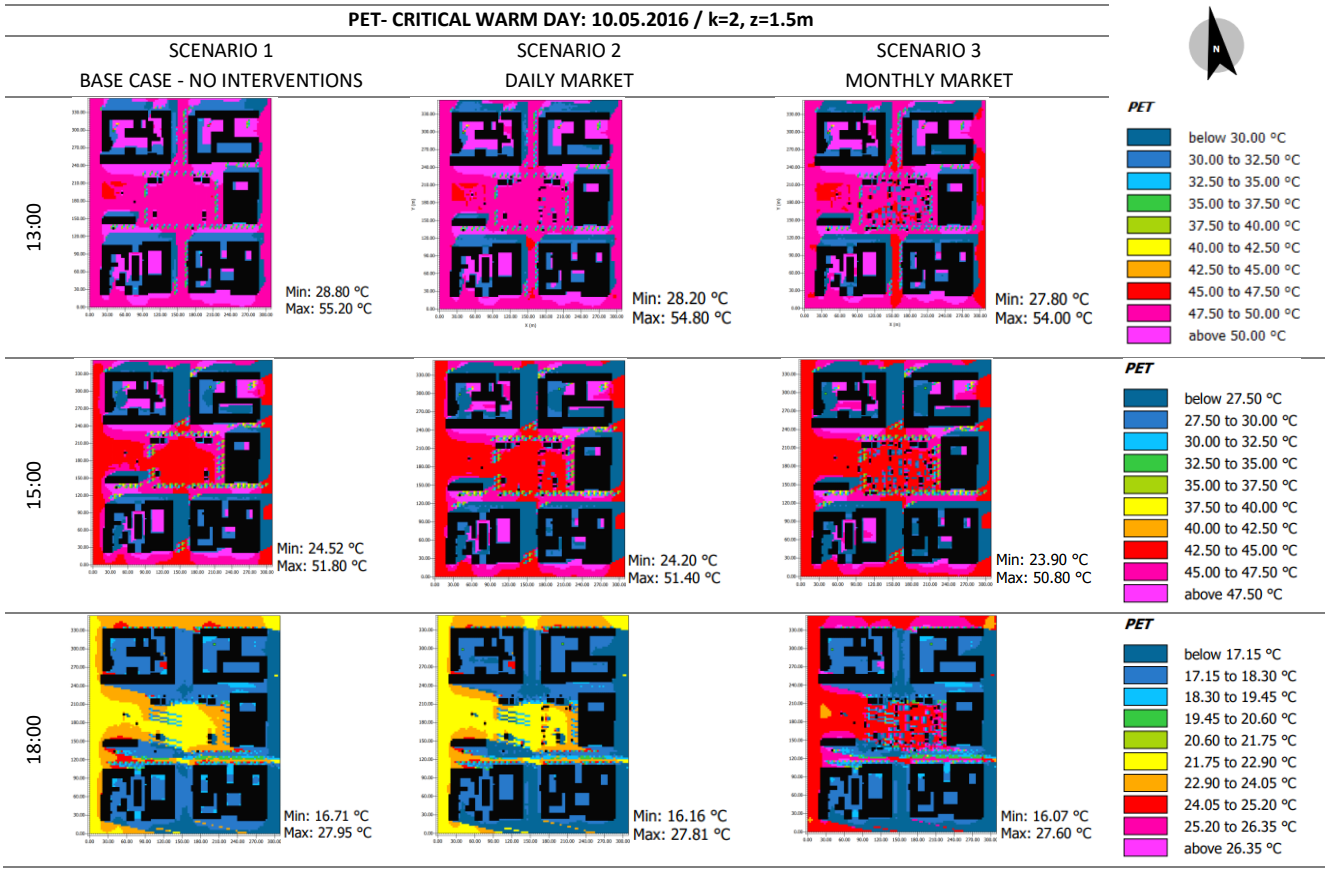


Physiological Equivalent Temperature (PET)

At 13:00, PET shows a significant temperature reduction in S3 compared to the other cases. The effect is not just in the square but also in the surroundings, especially in Mariankatu street. However, in the evening, S3 presents a temperature rise.

Considering the original PET ranges in terms of thermal perception (Figure 7), at 13:00, the space under the tents, umbrellas, and vehicles with sun sails can be categorized as “warm”. The plaza is shown mainly as “Very Hot” in all scenarios at 13:00 and 15:00. In the evening, S2 is “comfortable”, and S3 is “warm”. Meanwhile, the trees’ canopies are “warm/ hot” in the first two hours and later are comfortable (comments in next section).

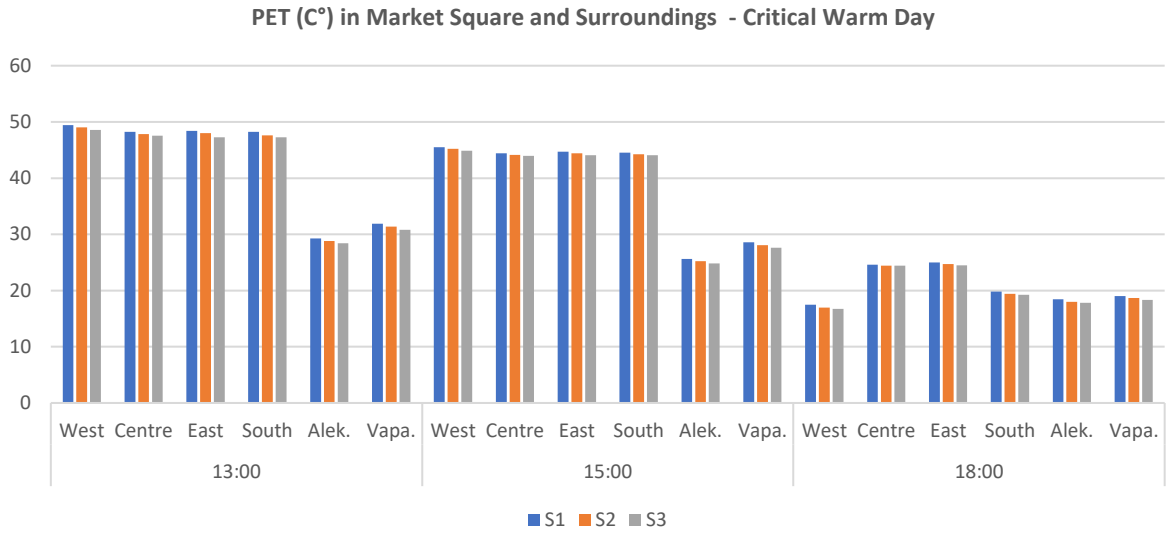
Table 15. PET - Critical Warm Day (Own elaboration, 2021)



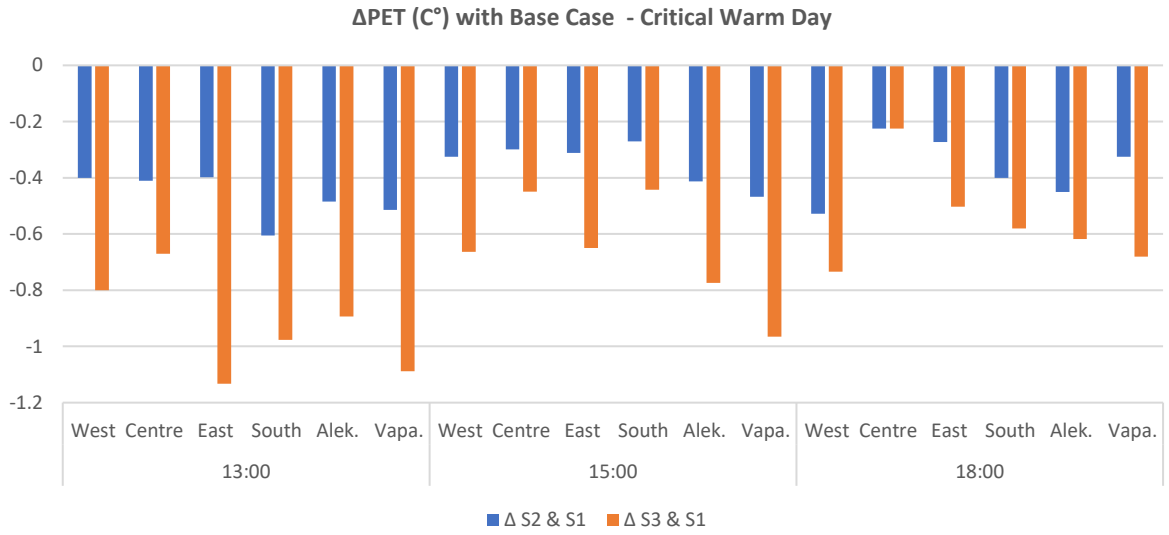
In all the cases, PET in the plaza areas mainly was higher than the surrounding streets, except in the evening, where the west had the lowest PET (Graph 49). Within the plaza, PET patterns changed throughout the day. The west side was the warmest area at 13:00 and 15:00; it was the east in the evening. It is essential to notice that all the points are closer to "comfortable" values at night.

S2 and S3 show a consistent cooling effect, reflecting the significance of temporary interventions during warm days (Graph 50). The maximum temperature reduction compared to the base case (Δ) were at 13:00: S2 in the south (-0.6°C) and S3 in the east (-1.13°C). In both cases, the lowest reduction took place in the centre at 18:00 (-0.23°C).

Additionally, the cooling effect is also present in the surrounding streets. In S2, Vapaudenkatu's main cooling effect occurred at 13:00 (-0.51°C) and 15:00 (-0.47°C), while in the evening, it was Aleksanterinkatu' s case (-0.45°C). In S3, the main difference between the streets was always in Vapaudenkatu. Although the streets presented lower temperatures than the Market Square at 13:00 and 15:00, at 18:00, the west side prevailed.



Graph 49. PET (C°) - Critical Warm Day (Own elaboration, 2021).



Graph 50. ΔPET (C°) - Critical Warm Day (Own elaboration, 2021)

Table 16. Summary of PET effects-Critical warm day (Own elaboration, 2021).

	DAILY MARKET (occupied area: 12%)	***MONTHLY MARKET (occupied area: 25%)***
13:00	Max Δ in South (-0.6 °C) / Min Δ in East (-0.4 °C) (↓)	Max Δ in East (-1.13°C)/ Min Δ in Centre (-0.67°C) (↓)
15:00	Max Δ in Vapaudenkatu (-0.47°C)/ Min Δ in South (-0.27°C) (↓)	Max Δ in Vapaudenkatu (-0.97°C)/Min Δ in South (-0.44°C) (↓)
18:00	Max Δ in West (-0.53°C)/ Min Δ in Centre (-23°C) (↓)	Max Δ in West (-0.73°C)/ Min Δ in Centre (-0.23°C) (↓)

Δ=difference

Chapter 6: Discussion

6.1. Temporary interventions effects and relevance

6.1.1. Microclimate and Thermal Comfort

The results demonstrate that existing temporary elements in the Market Square have microclimate and thermal comfort effects. Table 17 summarizes and compares the effects found in the previous chapter. Results are different in magnitude or contrasting according to the weather conditions, time of the day and locations of the plaza. Additionally, the quantity of elements or occupancy percentage is also relevant to outdoor thermal comfort (PET).

On the warm day, potential air temperature presented cooling effects; in contrast, the cold day had a negligible impact. The air temperature had a lesser impact compared with MRT and PET. This situation was predictable considering other studies (Maharoof et al., 2020). Furthermore, strategies that lead to air temperature changes (cooling on warm days or warming on cold days) may not necessarily lead to better thermal comfort (Emmanuel et al., 2007).

On the other hand, MRT showed more contrasts within the plaza. The occupied area clearly influenced the effect. The results show that at 13:00 on the warm day, MRT between the Monthly market's tents had similar values to the Alatori Park, which has grass. In the questionnaire, people indicated this time as one of the most visited hours in Spring. Moreover, temporary elements present benefits regarding budget and practicality (Nouri, 2015), while grass presents other benefits like permeability, evaporative cooling, and biodiversity enhancement (Duarte, 2016).

The temporary elements' effect is also cooling on the cold day, but evidently, it is not beneficial for thermal comfort. Additionally, the shadow projection of the surrounding buildings varies between days; on the warm day, the shadow mainly affects the plaza's perimeter at 18:00; on the cold day, it covers half of it. It is essential to mention that ENVI-met overestimates MRT during daytime and underestimates it during the night because no energy is stored (Emmanuel et al., 2007).

In the case of the outdoor thermal comfort, the ephemeral structures generate a more variety of microclimates, which is a good situation for the users to find the area more adequate to their own comfort (Thorsson et al., 2004; Martinelli, 2015; Oke et al., 2017). Spaces underneath the existing temporary shading elements (umbrellas/sun sails/tents) present colder PET values than the open-air area during the warm and cold days. However, it is essential to mention that the vendors or clients use them, but not the public. "Public" sun protection is available under the trees and shadow projection of the surrounding buildings and modules/vehicles temporary elements. The relevance of shaded spaces is highlighted in previous Swedish research, in which 25%–55% of the visitors of a park seek shade during warm and sunny conditions (Thorsson et al., 2004).

Table 17. Microclimate and Thermal Comfort effects of Temporary Elements in Market Square (Own elaboration, 2021).

	COLD DAY	***WARM DAY***
Potential Air Temp.	• No notorious effect, as expected.	• Cooling effect (↓) • Shelter canopies: inner temperature warmer (15:00 & 18:00) than the open-air area
MRT	• 13:00 lower MRT in the plaza (S3) (↓), except for TI perimeter • 15:00 lower MRT in the plaza (↓), except for TI perimeter • 18:00 lower MRT in the plaza (↓), Reduction of trees' warming effect. (↓). • Temporary Interventions (TI): 13:00 & 15:00 inner MRT lower than open-air (↓)/ 18:00 higher (↑)	• 13:00 cooling effects (S3>S2) (↓), except for TI perimeter. MRT values are similar to near vegetation • 15:00 no notorious effects • 18:00 higher MRT in the plaza between elements (S3>S2) (↑), Reduction of trees' warming effect. (↓) • Temporary Interventions (TI): inner MRT lower than open-air (↓)
PET	• **The effect varies (↓) (↑)** • Warming effect (perimeter of TI) (↑) • TI: inner temperature is colder than open-air areas at 13:00 & 15:00 (↓), but warmer at night. (↑) • 13:00 PET close to comfortable values. • 18:00 no relevant impact, not suggested for activities	• **Cooling effect (↓)** • Cooling effect (perimeter of TI) at 13:00 (↓)/warming effect at 15:00 &18:00 (↑) • TI: inner temperature is always cooler than open-air areas. (↓) • Reduction in trees' warming effect (15:00 & 18:00) (↓) • 18:00 PET close to comfortable values. • Mariankatu has a notorious cooling effect at 13:00 and 18:00. (↓) *Δ = difference

Additionally, the immediate surroundings of the temporary interventions showed PET rise in most cases except for 13:00 on the warm day. The effect might be due to wind protection, materiality, arrangement of the elements and occupancy of the market.

On the warm day, the monthly market showed better thermal comfort effects at 13:00, while the daily market at 18:00. It is important to remember that typically, the monthly market operates until 15:00 and varies during the daily market. However, PET values at 18:00 are very close to "comfortable" levels and are highly recommended for outdoor activities.

Meanwhile, results related to the thermal comfort in the cold case seem far from reality. Most values at 13:00 are close to "comfortable" ones, but when checking meteorological data, time presented snow and a partially covered sky. PET's overestimation is because ENVI-met does not consider rain or snow in the simulations (Helge, 2017). Clarified this issue, ephemeral structures have a warming effect in the southern part of the plaza, especially at 13:00, which is also close to "comfortable" values. At 15:00, PET shows values considered "very cold" to "slightly cold", and interventions' perimeters shows a slightly warming effect. Both hours show a more positive effect in the Monthly Market. Nevertheless, 18:00 presents "very cold" values and further proposals do not seem promising to significant improvements.

Trees' canopies show various PET ranges, mostly colder than their immediate surroundings. A warming effect around trees is found mainly in the evening due to the blocking of airflow in combination (Maharoof et al., 2020), which is reinforced with an alignment of buildings on the right side of the plaza and create a semi-confined area that lowers the wind speed (Cheung & Jim, 2018).

The benefits of vegetation go beyond artificial canopy shelters because they impact shading together with evapotranspiration (Duarte, 2016; Cheung & Jim, 2018). Additionally, trees reduce the spatially averaged values of MRT on cold and warm days (Gatto et al., 2020). Considering that all the existing trees are permanent, proposals can explore mobile modules with vegetation. Existing flower boxes (flower stores and terraces) were not considered during the simulations.

The materials used for the simulation were PVC, metal, and wood[2], and consider existing typologies. The study did not contemplate colour differences because materials datasheets were not found (e.g., white-and-red striped PVC). Nevertheless, studies suggest density (Lin, 2016) and albedo (Maharoof et al., 2020) could affect results.

6.1.2. Other benefits of Temporary Solutions

Another reason for considering temporary elements in the Market Square is the contrast between seasons. Furthermore, spring is a transitional season that goes from very cold to warm days. The variety of weather conditions imply different needs. In the case of spring, it is a transitional season from freezing temperatures to warm days. Other relevant changes are the increase of sunlight hours, the decline of snow, and the increase of sunny and dry days. Ephemeral installations, like shading devices, could ensure the site's flexibility required by weather changes (Martinelli et al., 2015).

Moreover, the climate change projections in Lahti show that the temperature will rise. Therefore, public spaces are relevant places for creating resilience and adaptability using short-term thermal responsive urban interventions (Nouri, 2015). Availability of choice between exposed and shaded areas throughout the year must be enhanced considering the escalation of warm days.

In the same line, the analysis of three hours also demonstrates changes in the microclimate and thermal comfort effects within a day. Temporary interventions open opportunities for adaptable solutions. Moreover, the hourly analysis determines more comfortable hours for outdoor activities and the identification of comfortable areas.

Finally, the area's historical value limits implementing significant structures that obstruct the ceremonial axis; nevertheless, it was possible to identify temporary installations in that location in different events. The traditional Christmas tree and the monthly market represent exceptions to the intangible area. Therefore, alternatives of the same nature for the thermal comfort proposals are possible.

[2] In this study, "Wood" material was created in ENVImet database with specifications retrieved from Santamouris, 2006.

6.2. Users' behaviour, meteorological conditions, and outdoor thermal comfort

The literature review exposed that thermal comfort composes of physiological and psychological aspects. Therefore, users' behaviour and preferences information were valuable to complement the microclimate and thermal comfort results.

The study presented a better picture of Lahti residents' behaviour towards the plaza in different seasons. People visit and spend more time in the square during summer, followed by spring and autumn, while winter had the worst results. Results were expected considering previous Swedish research (Yang et al., 2017, Thorsson et al., 2004, Eliasson et al., 2007) because compared to winter, summer has higher air temperature, more sun hours, and clear days. Nevertheless, autumn presents more overcast days than spring. Therefore, it was expected to have fewer visits than the second, but results present similar behaviour. However, the pandemic has shown an increase in the use of outdoor spaces, regardless of the weather conditions.

Additionally, more people considered that the Market Square was comfortable during warmer days than colder days. Users' perception aligns with the PET study, in which existing temporary elements had better effects regards thermal comfort in the critical warm day.

Interviewees also expressed the relevance of weather in the plaza's dynamics, where summer is the most liveable season, winter has reduced activities, and spring is a transition between them. Moreover, the weather for a monthly market determines the number of vendors because, on cold weather-unfavourable days, the lesser public is expected; hence, the area occupancy is also affected.

The range hours in which people prefer visiting the square is 15:00-18:00, followed by 12:00-15:00 in all the seasons. Compared to winter, spring showed a significant increase in the 15:00-18:00 and decrease of 12:00-15:00. The preference for the second most popular hours relates to higher T_{Air} and PET hours in the warm and cold critical days; however, the most voted range hours show a decrease in both parameters. In addition, at 15:00, temporary elements showed punctual cooling effects underneath shaded areas, but other hours had widespread effects in the plaza. So, the preference for visiting hours is due to psychological aspects more than physiological factors. Most of the participants are in the working-age group, and regular office hours finish at 16:00, so daily routines play an essential role too. The definition of the most visited hours supports design decisions to respond to specific needs (Martinelli et al., 2015).

Results indicate that the primary motivation for visiting the plaza is for its commercial activities. Additionally, all the assessed temporary interventions in May were related to commerce. Therefore, temporary elements support and allow different activities, which in parallel attract the public. Results align with the placemaking theory (Madden & PPS, 2001), which establishes that uses and activities are important factors for the success of public spaces.

On the other hand, there is an abrupt decrease in visiting hours from 6pm-9pm. According to the warm day analysis, 6pm is the most comfortable hour in the plaza, so the lack of visits is mainly related to the absence of evening activities. In parallel, the survey also showed that people are eager for more evening events. Hence, thermal comfort modelling results need to be analysed in detail to align with pedestrians' preferences (Nouri and Costa, 2017).

The survey results show a common perception of the lack of shaded areas, wind protection and rain protection on critical days. Therefore, more variety of microclimates in the plaza are desirable, which are enhanced by implementing more and different ephemeral interventions. Improving these aspects will give more options to the users to adapt to the thermal environment.

6.3. Opportunities to improve the Market Square

Results indicate that evening events are desired in the area, which is an opportunity to implement temporary interventions and activate the plaza. The most voted activity for the evening were cultural events, followed by coffee shops and food vendors. During the daily and the monthly market survey, no cultural events or similar interventions were identified. The new activities are complementary between them. During the study, the daily market had coffee shops and food vendors; however, users claimed to extend their opening hours and implement more options. The idea is supported by experts' proposals who expose that microclimatic interventions could improve thermal comfort levels and potentially increase activities (Nouri, 2015). Other citizens' desires include public art, plants and benches.

In this same line, interviews revealed plans for the Market Square for temporary elements. Therefore, it is convenient to consider three steps in the design process: understand the microclimatic constraints, provide physical responses, and influence thermal comfort (Nouri and Costa, 2017).

The daily market is present all the month except for one day of the month. Therefore, its effects have more impact on the liveability of the city centre than the monthly market. Nevertheless, the insertion of the monthly market needs to be contemplated. The microclimate and thermal comfort analysis showed that in most cases, the monthly market had better performance than the daily market due to more occupancy. More daily activities and interventions could bring positive effects to the study area.

Summer activities in the plaza were not part of the study, but it was possible to observe longer opening hours in some daily market selling spots. Additionally, a temporary intervention mentioned in the interviews was implemented in the west area of the market. It was called "*Lahen Lava 2021*" and included a stage, urban furniture and vegetation, and a calendar of performances. The example demonstrates the flexibility of the place and the interest in the competent authorities to improve the area with innovative projects.

6.4. Considerations for future temporary interventions

Table 18 summarises the identified strategies for improving the Market Square with temporary interventions during critical cold and warm days in spring. The strategies aim to provide comfortable environments and increase liveability in the city centre. As exposed before, both goals are linked with the use of temporary interventions.

On the one hand, microclimate and thermal comfort strategies consider lessons taken from the simulation analysis. The increase and decrease of PET are desirable for the corresponding days; however, the primary strategy is to provide various microclimates to the user. Specific strategies for the cold day include rain/snow protection and wind protection, while shaded areas and vegetation modules are proposed in the case of a warm day. The Monthly Market generally showed better results than the daily market, so increasing the occupancy percentage and creating clusters of ephemeral elements is a common strategy on both days.

In the case of activities, the central aspect is to consider users' desires. In this case, users wanted more activities, urban furniture, and art. The additions of these elements support the previously mentioned strategies because they give significance or use to new temporary interventions. Additionally, the enhancement of events at certain day hours is considered the most comfortable PET ranges found in the analysis.

Contemplating that spring is a transitional season and progressively warmer, strategies for cold days are ideal for the first half of the month, and warm days' strategies for the second half. Possibly they can also be implemented in other seasons.

Table 18. Considerations for New Temporary interventions (Own elaboration, 2021).

		Critical Cold Day	Critical Warm Day
Microclimate & Thermal Comfort	Increase PET	X	
	Decrease PET		X
	Variety of microclimates	X	X
	Shaded areas		X
	Rain/snow protection	X	
	Wind protection	X	
	Vegetation mobile modules		X
	Create Clusters in Layout	X	X
	Increase % of occupancy	X	X
Activities & more interventions	Consider users' desires	X	X
	Enhance evening Open air Activities		X
	Enhance noon Open air Activities	X	

6.5. Proposals and Validation

The exposed considerations for temporary interventions are developed in two explorative proposals. They focus on the daily market because it serves the community for most of the

month. Additionally, it presented less favourable conditions than the monthly market. The monthly event would need to be adjusted according to the proposals. Proposals take into account the Placemaking theory.

6.5.1. General strategies

The general strategies enhance the existing positive characteristics of the study area (Figure 32). On one side, it encourages the so-called "ceremonial axis", which currently has a historical significance. The plaza is lower than the church and the city hall, giving good views of the city landmarks. It also takes advantage of Aleksanterinkatu dynamics. In the Monthly Market, it is possible to observe the allocation of multiples selling sports in this street for attracting passing people. Therefore, the street is a strategic access point for the plaza, and all pedestrians are potential users.

The selection and distribution of temporary elements will apply previously mentioned considerations (Table 18). Nevertheless, it would use existing elements and reorganized them in a new layout. Moreover, it considers new interventions that respond to the new uses, allow space flexibility, and permit the visibility of the landmarks.

The constant division of the west and east sides of the plaza is considered a problem because those areas generally do not interact. Additionally, the centre is not a comfortable place most of the time because it is empty. So, the proposal considers connecting both areas with cultural and leisure areas to complement different uses and generate better microclimatic results. The area is allocated in the middle of the plaza, so the ceremonial axis is re-signified as the "cultural axis". New activities include a performance stage, leisure area and open-air exhibitions.

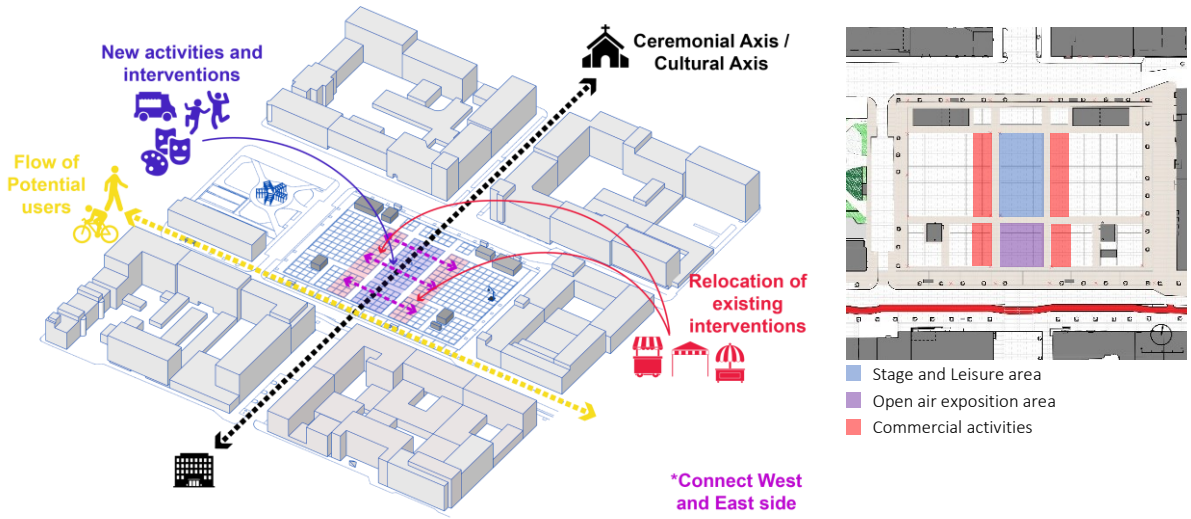


Figure 32. General strategies and zoning for proposals (Own elaboration, 2021)

The implementation of any of the following proposals requires the participation of all the stakeholders. The city of Lahti should be responsible for the cultural axis considering it is beneficial to all the residents and can attract more people to the city centre, and even people

from other areas. The area can be rented to Lahentori in a similar scheme to the one they have for the winter ice rink. Finally, the proposal needs to be approved by the corresponding authorities.

6.5.2. Cold Day Proposal

The proposal for the critical cold day relocated the existing temporary interventions and connected the existing terraces to the cultural axis. Relocation also considered the creation of clusters for better microclimate performance. New temporary elements are focused on cultural activities. It includes a "stage-truck" which allow multiple uses: different performances (e.g., theatre, music), conferences, indoor exhibitions, movies projections and a mobile library. Advantages also include the ease of changing location (within the plaza or in other city areas) and can be reused in other seasons. It also includes domes with a transparent canopy allocated in front of the stage. The domes are proposed as part of the public domain, giving users a space with wind, rain, and snow protection for leisure. The structures are easy to install and are used in other cold areas, especially as a Covid-19 alternative for restaurants and bars (Billock, 2020; Chiu, 2020).

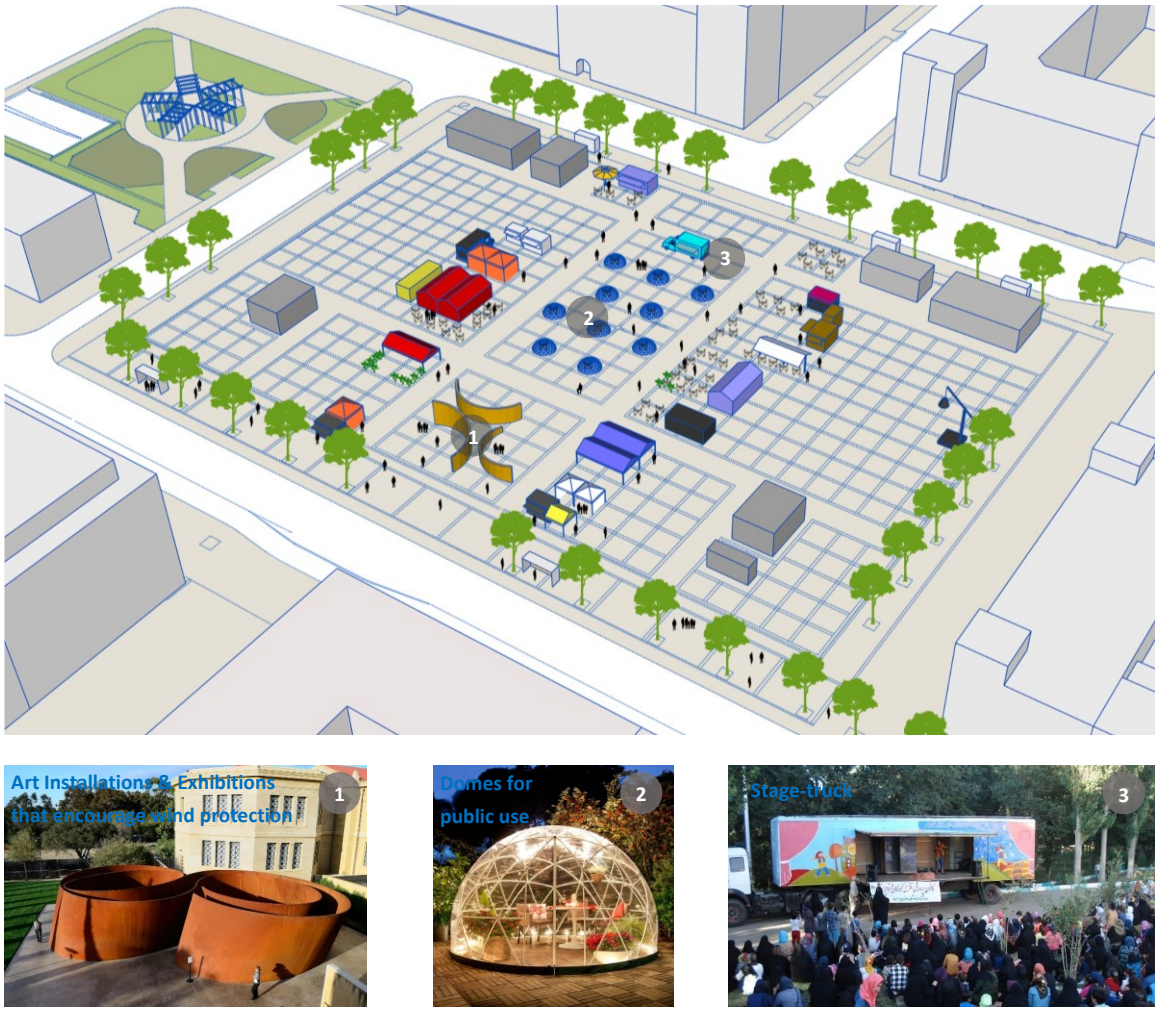
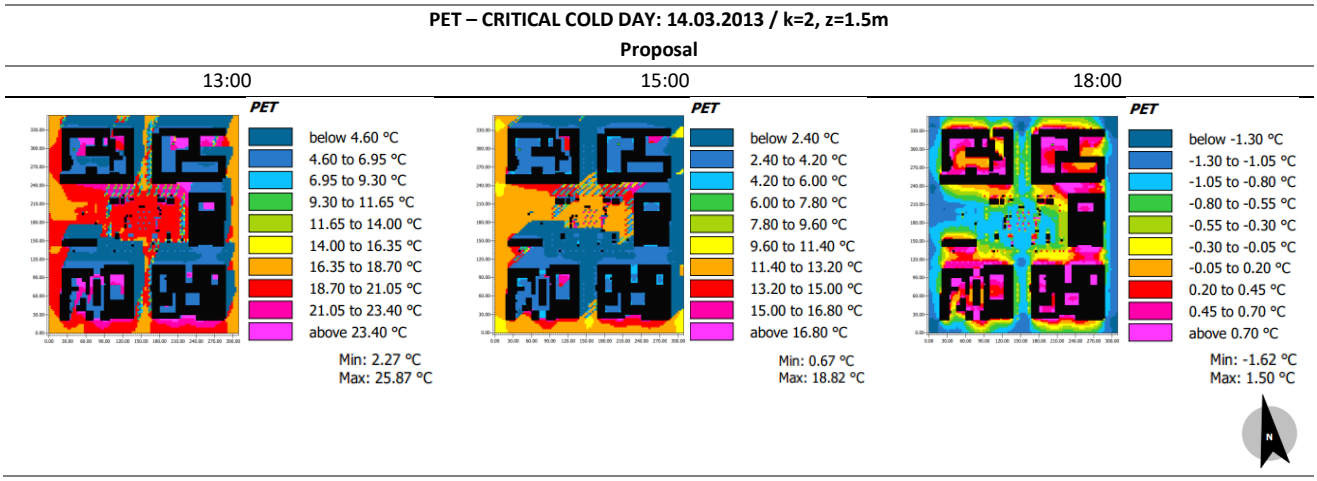
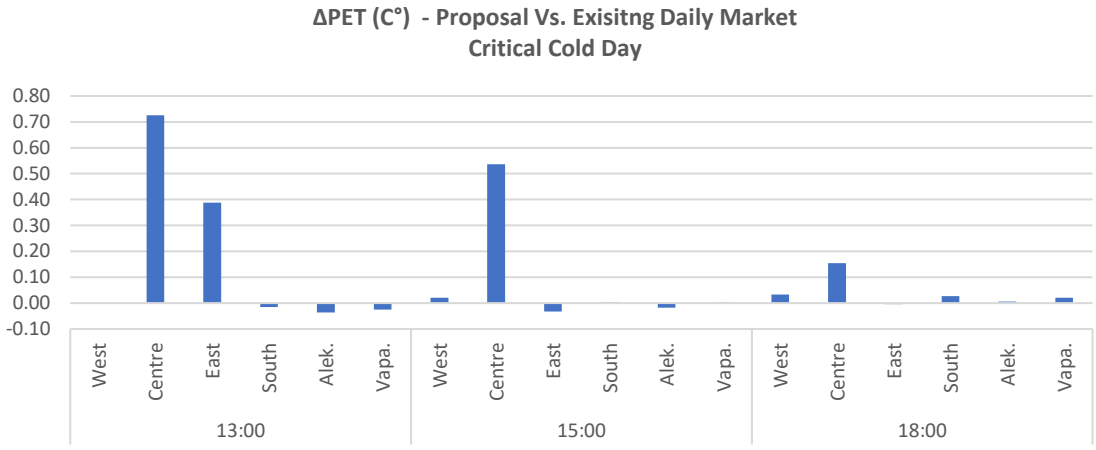


Figure 33. Proposal for Critical cold day (Own elaboration, 2021 images retrieved from arts.stanford.edu, 2019; gardenigloo.com, n.d.; honaronline.ir, 2017).

Table 19. PET – Proposal for Critical Warm Day (Own elaboration, 2021)





Graph 51. ΔPET (C°) - Proposal Vs. Existing Daily Market Critical Cold Day (Own elaboration, 2021).

6.5.3. Warm Day Proposal

The critical warm day proposal differs from the previous one because the intervention in the central area considers the *Lahen Lava 2021* project. The original project was in the west area, including a conventional stage, four trees and other plant's boxes, and a leisure area. The decision is based on the following questions. What would have happened if the project had been done during spring? Or what microclimate effect would it have by allocating it closer to the commercial activities? Additionally, it is a practical proposal if the results were positive because the existing elements could be reused.

Another change with the previous proposal is that the exhibition area could enhance artificial canopies or vegetation during this period.

ENVI-met results show an essential improvement for outdoor thermal comfort compared to the existing situation. Graph 52 exposes that all areas increase their PET values by less than 0.43°C, the central area presents a decrease of -16.91°C and -13.52°C during the most visited

hours. The difference is mainly due to vegetation, which, as mentioned before, offers additional benefits than artificial interventions. The users have more variety of microclimates for finding their preferences. Additionally, considering the Nordic behaviour for sunny and warm days, the three studied hours are optimal. However, the evening is the best hour regarding thermal comfort for outdoor activities; therefore, events should be encouraged during this time.

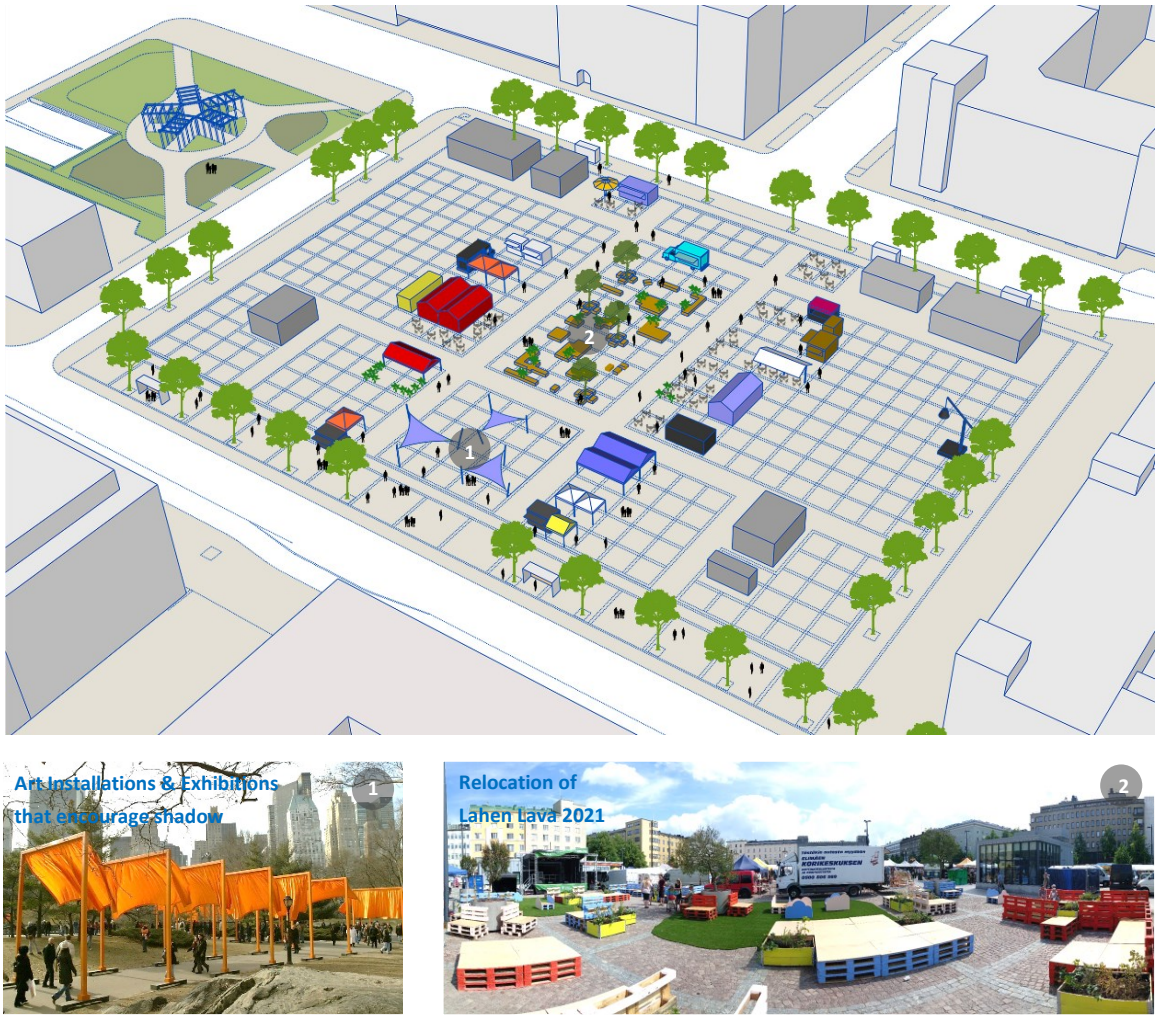
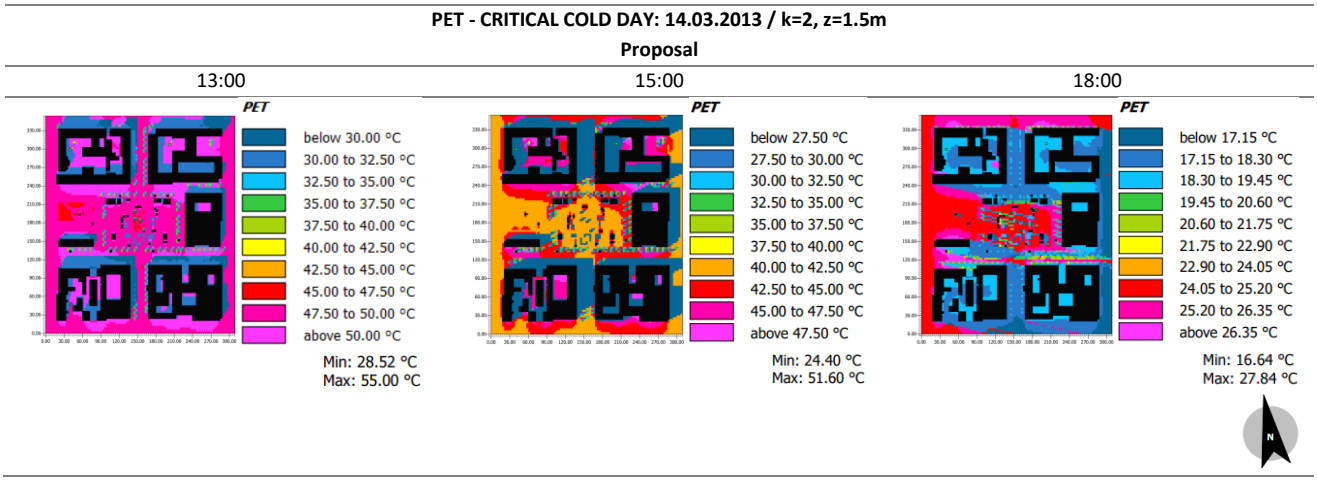
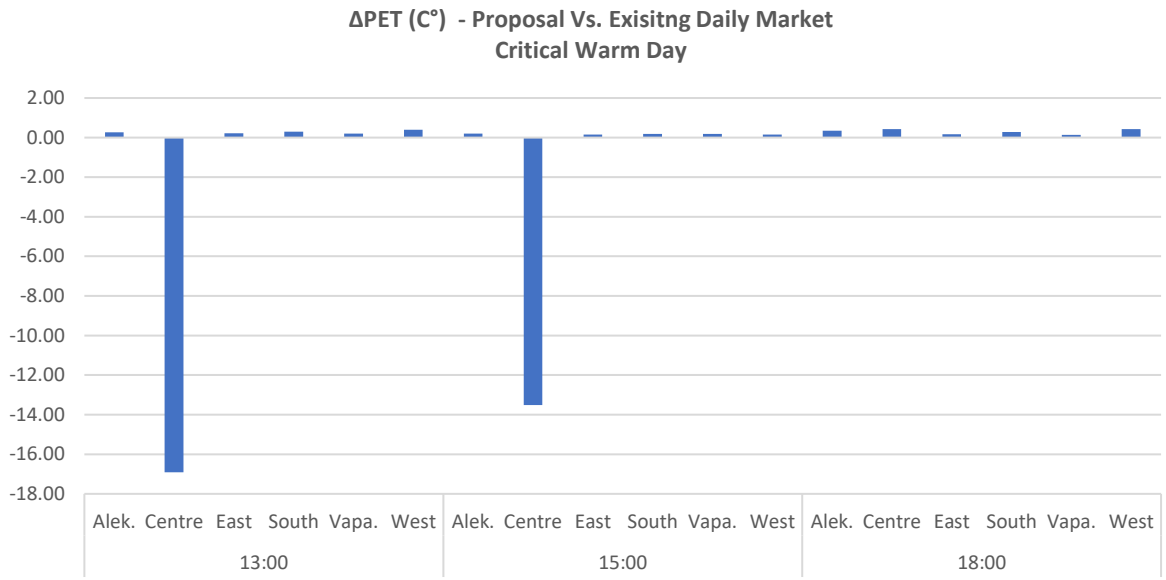


Figure 34. Proposal for Critical warm day (Own elaboration, 2021 image retrieved from Willens, 2005).

Table 20. PET – Proposal for Critical Warm Day (Own elaboration, 2021)





Graph 52. ΔPET (C°) - Proposal Vs. Existing Daily Market Critical Cold Day (Own elaboration, 2021).

6.5.4. Comments

Both proposals had demonstrated the benefits of including more temporary elements than the existing distribution in the daily market. The proposals improved the environment in terms of thermal comfort; nevertheless, interventions on the warm day had a more significant impact as expected. Temporary elements also host new activities, taking into account people's desires and participation. Hence, the plaza will become more attractive, will receive more public and have more active hours.

The implementation of any project requires the cooperation of the stakeholders and the approval of the corresponding authorities. They must consider the overall benefit that the proposals would have in the social, cultural and economic spheres.

6.6. Limitations

- Measurement instruments & model
    - The study focused on two critical spring days, mainly for time restrictions. Nevertheless, it would have been positive to include a "regular" day in the analysis to understand the seasonal effects fully.
    - ENVI-met does not consider rain or snow during the analysis, which indirectly affects outdoor thermal comfort. The programme also has limitations for considering wind dynamics.
    - The model used a 3x3x3 grid for optimizing the rendering time. A higher resolution would have brought more detailed analysis and proposals.
    - Some PET results seemed unreasonable (e.g., obtaining comfortable levels during the critical cold date). Therefore, the model needs to be checked. It is recommended to install another datalogger in the study area that measures temperature and relative humidity for more specific data for the simulations.
    - The model presented good RSME results for the daily and monthly market on a cloudy day, but not during a sunny and clear day. The model needs to be reviewed, and more calibration exercises should also be done in other seasons.
    - High RSME presented on sunny days could be a result of the radiation influence. The weather meter (Kestrel 3000) did not indicate the need to protect it from the sun. At the same time, the datalogger (Tinytag) used a crafted radiation shield instead of the one indicated by the manufacturers.
    - During the traverse survey, Kestrel 3000 was hard to handle (e.g., maintaining the same height and knowing when to stop the data). The instrument might have led to human errors. It is recommended to replace the exercise with a datalogger.
    - The city's current meteorological station do not present wind direction or wind speed data. For practical reasons, the study assumed that the data was equal to a previous study in Lahti. Moreover, the wind is a critical topic in terms of thermal comfort.
- Questionnaire & Users behaviour
    - The pandemic situation forced the study to change the questionnaire into an online one. A face-to-face method allows other valuable questions (e.g., perceived thermal stress during the survey).

- Just 12% of the respondents were over 60 years old. According to the market's host, this is an essential group of users, but the online questionnaire probably limited their participation.

- The study considered the online questionnaire results for the most attended hours in the season to select the meteorological and thermal comfort analysis hours. Nevertheless, counting the attendance during the field survey would have given more realistic attendance findings and their correlation with the weather conditions.

Chapter 7: Conclusions

Temporary interventions positively affect outdoor thermal comfort in the study area, with better results in warmer days than colder ones during spring. In the microclimate analysis, it was concluded that the main reason was their impact on MRT, while the effects in potential air temperature were negligible. Moreover, different considerations are proposed according to the weather characteristics.

On the other hand, users' behaviour for attendance shows that the most visited hour is not necessarily the one with more outdoor thermal comfortable ranges. Reasons are linked with psychological adaptation factors of locals, e.g. preferences for sunshine and expectations, time availability in the users' routine and activities in the plaza. Design proposals need to consider the needs of the most visited hours and enhance the plaza's use with more comfortable ranges by implementing more uses to attract people. Additionally, they should cover users' desires for more activities during the evening.

Additionally, implementing more climate-sensitive strategies in the plaza would lead to more comfortable spaces and microclimate-diverse public spaces. The two presented examples show positive outcomes, but interventions in the warmer days should be prioritized due to significant results.

The presented proposals for the market square require the cooperation of different stakeholders. If so, the area would be more thermally comfortable and attractive. Additionally, the city centre would become more liveable, which is positive for business (within and around the plaza) and citizens.

Finally, Climate Change would bring undeniable temperature rise with uncertainties related to time (when?) and magnitude (how much?); therefore, it is mandatory to find solutions that cope with them. Aside from the microclimatic advantages, temporary interventions in public spaces are low budget, flexible, and adaptable to different scenarios. They must be considered as climate change adaptation and mitigation solutions and be included in formal plans. It is highly recommended to include microclimatic studies in the design process of any new proposal.

Recommendations for future studies

- Reproduce study in other seasons in the Market Square to define suitable CSUD proposals. A yearly analysis would give a better panorama for plans on the site. Moreover, they would confirm if the presented temporary element's effects are similar in other seasons.

- In parallel, develop an ENVI-met model for the area which works for all the year. Additionally, the model should consider more detailed materials that would need to be added to the programme's database (e.g., PVC colours).

- Design other temporary proposals for the site using the presented recommendations for cold and warm spring days.

- The original PET index and thermal sensation have been questioned in other Nordic contexts. Therefore, the PET index should be evaluated for Finland to understand local outdoor thermal comfort better.

- Develop a cost-benefit analysis to implement the presented proposals, which would be useful for the decision-making process. The evaluation should consider the square and its surroundings.

- Evaluate temporary interventions in other contexts. The methodology used in this thesis is a baseline to other studies and is helpful to improve other public spaces. Additionally, it would help to find practical, low-cost, and context-specific climate change adaptation solutions.

References

1. AIHEESTA,L.L., 2021. *Lahen Lava tuo torille elämää ja tukee koronan kurittamia tapahtumajärjestäjiä.* Lahti: June 18, [viewed July 28, 2021]. Available from: https://www.ess.fi/paikalliset/4192136?fbclid=IwAR2JqEKQ3_GzmXWsGAGeM6zcw2HgXAUp7A9E420YVRnUJtqs4pxt8RxmB1I.

2. AJUNTAMIENTO DE BARCELONA., n.d. *Barcelona for Climate.* n.d., [viewed 25 February 2021]. Available from: https://www.barcelona.cat/barcelona-pel-clima/en/climate-change-barcelona/our-activity-affects-climate.

3. ANDRES, L. & ZHANG, A.Y., 2020a. *Transforming Cities Through Temporary Urbanism.* Cham: Springer International Publishing AG Available from: https://ebookcentral.proquest.com/lib/[SITE_ID]/detail.action?docID=6427573.

4. ANDRES, L. & ZHANG, A.Y., 2020b. *Transforming Cities Through Temporary Urbanism A Comparative International Overview.* 1st ed. Cham: Springer International Publishing.

5. ARGOTA SÁNCHEZ-VAQUERIZO, J. & CARDOSO LLACH, D., 2019. *The Social Life of Small Urban Spaces 2.0: Three Experiments in Computational Urban Studies. The Social Life of Small Urban Spaces 2.0: Three Experiments in Computational Urban Studies.* Singapore: Springer Singapore.

6. arts.stanford.edu., 2019. *Richard Serra's Sequence.* [viewed 29 July, 2021]. Available from: https://arts.stanford.edu/event/81452/.

7. ASHRAE., 2009. *2009 ASHRAE handbook.* SI ed. ed. Atlanta, Ga: ASHRAE.

8. BAZAZ, A., BERTOLDI, P., BUCKERIDGE, M., CARTWRIGHT, A., DE CONNINCK, H., ENGELBRECHT, F., JACOB, D., HOURCADE, J., KLAUS, I., DE KLEIJNE, K., LWASA, S., MARKGRAF, C., NEWMAN, P., REVI, A., ROGELJ, J., SCHULTZ, S., SHINDELL, D., SINGH, C., SOLECKI, W., STEG, L.&WAISMAN, H., 2018. *Summary for Policy Makers What the IPCC special report on global warming of 1.5°c means for cities.* C40 Cities Climate Leadership & Group Global Covenant of Mayors.

9. BILLOCK,J., 2020. *The New Normal of Dining Out.* June 5, [viewed 28 July, 2021]. Available from: https://www.smithsonianmag.com/travel/new-normal-dining-out-180974971/.

10. BIRD, T., 2017. Nordic Action on Climate Change(766). Available from: http://urn.kb.se/resolve?urn=urn:nbn:se:norden:org:diva-4980 DOI 10.6027/ANP2017-766.

11. BROWN, R.D., 2010. *Design with microclimate: the secret to comfortable outdoor spaces.* Island Press Available from: http://www.vlebooks.com/vleweb/product/openreader?id=none&isbn=9781597269896&uid=none.

12. BRUSE,M., 2014. *Using ENVI-met BioMet... A quick guide.* [viewed July 15, 2021]. Available from: https://envi-met.info/public/files/docs/Quickstart_biomet.pdf.Ley General de Cambio Climatico2012, .

13. CAMPBELL, S., REMENYI, T.A., WHITE, C.J. & JOHNSTON, F.H., 2018. Heatwave and health impact research: A global review. *Health & Place.* **53**, pp. 210-218. Available from: http://dx.doi.org/10.1016/j.healthplace.2018.08.017 DOI 10.1016/j.healthplace.2018.08.017.

14. CASAGRANDE, M., 2019. *From Urban Acupuncture to the Third Generation City. From Urban Acupuncture to the Third Generation City.* Cham: Springer International Publishing.

15. CAWEEN, A., 1878. *Lahti town plan from 1878.* [viewed July 15, 2021]. Available from: https://commons.wikimedia.org/wiki/File:Alfred-Caweenin-asemaaka-vuodelta-1878.jpg.

16. Chan Myae Aung., 2020. *The Recovery Will Happen in Public Space.* [viewed 5 January 2021]. Available from: https://www.pps.org/article/the-recovery-will-happen-in-public-space?fbclid=IwAR3hovB-NtqsLkJwc7uZjF7GR3obJaJhTLD-l49iahHrpyK-WULrhBpJm2s.

17. CHEN, Y. & WONG, N.H., 2006. Thermal benefits of city parks. Available from: http://scholarbank.nus.edu.sg/handle/10635/45871.

18. CHEUNG, P.K. & JIM, C.Y., 2018. Comparing the cooling effects of a tree and a concrete shelter using PET and UTCI. *Building and Environment.* **130**, pp. 49-61. Available from: https://dx.doi.org/10.1016/j.buildenv.2017.12.013 DOI 10.1016/j.buildenv.2017.12.013.

19. CHIU, A., 2020. *Dining bubbles are popping up everywhere, but are they safe? Experts weigh in.* November 2, [viewed 28 July, 2021]. Available from: https://www.washingtonpost.com/lifestyle/wellness/dining-bubble-pod-safe-covid/2020/10/31/b4eeb00a-1a31-11eb-aeec-b93bcc29a01b_story.html.

20. City of Beacon., 2020. *Main Street Parklet Program Applications and Guidelines.* [viewed 5 January 2021]. Available from: https://www.beaconny.gov/index.php/2020/06/12/main-street-parklet-program-applications-and-guidelines/.

21. DUARTE, D. 2016. Vegetation and climate-sensitive public spaces In: R. EMMANUEL ed., *Urban climate challenges in the tropics: rethinking planning and design opportunities* London: Imperial College Press, pp. 111-162.

22. DUARTE, D. 2015. *O impacto da vegetação no microclima em cidades adensadas e seu papel na adaptação aos fenômenos de aquecimento urbano. Contribuições a uma abordagem interdisciplinar.* University of São Paulo.

23. ELIASSON, I., KNEZ, I., WESTERBERG, U., THORSSON, S. & LINDBERG, F., 2007. Climate and behaviour in a Nordic city. *Landscape and Urban Planning.* **82**(1), pp. 72-84 DOI 10.1016/j.landurbplan.2007.01.020.

24. EMMANUEL, R., ROSENLUND, H. & JOHANSSON, E., 2007. Urban shading—a design option for the tropics? A study in Colombo, Sri Lanka. *International Journal of Climatology.* **27**(14), pp. 1995-2004 DOI 10.1002/joc.1609.

25. EMMANUEL, R., 2016a. Achieving Thermal Pleasure in Tropical Urban Outdoors. In: R. EMMANUEL ed., *Urban climate challenges in the tropics* London: Imperial College Press, pp. 31-50.

26. EMMANUEL, R., 2016b. Introduction. In: R. EMMANUEL ed., *Urban climate challenges in the tropics : rethinking planning and design opportunities* London: Imperial College Press, pp. 1-30.

27. EMMANUEL, R., 1993. A Hypothetical 'Shadow Umbrella' for Thermal Comfort Enhancement in the Equatorial Urban Outdoors. *Architectural Science Review.* **36**(4), pp. 173-184. Available from: http://www.tandfonline.com/doi/abs/10.1080/00038628.1993.9696759 DOI 10.1080/00038628.1993.9696759.

28. ERELL, E., PEARLMUTTER, D. & WILLIAMSON, T., 2011. *Urban microclimate designing the spaces between buildings.* 1st ed. London ;: Earthscan.

29. EVANS, G.W., 2019. Projected Behavioral Impacts of Global Climate Change. *Annual Review of Psychology; Annu Rev Psychol.* **70**(1), pp. 449-474 DOI 10.1146/annurev-psych-010418-103023.

30. evergreen.ca., 2021. *Has COVID-19 Given New Life to Tactical Urbanism?* [viewed 5 January 2021]. Available from: https://www.evergreen.ca/blog/entry/has-covid-19-given-new-life-to-tactical-urbanism/.

31. FERRARI, S. & ZANOTTO, V., 2016. *Building Energy Performance Assessment in Southern Europe.* 1st ed. Cham: Springer International Publishing.

32. FINNISH METEOROLOGICAL INSTITUTE., n.d.b. *Seasons in statistics by calendar month.* n.d.b, [viewed 2 February 2021]. Available from: https://www.ilmatieteenlaitos.fi/vuodenaikojen-tilastot.

33. FINNISH METEOROLOGICAL INSTITUTE., n.d.a. *Download observations.* n.d.a, [viewed May 10, 2021]. Available from: https://en.ilmatieteenlaitos.fi/download-observations.

34. FULADLU,K., RİZA, M.&İLKAN, M., 2018. *The Effect Of Rapid Urbanization On The Physical Modification Of Urban Area.* RENECON International. May 22, Available from: http://hdl.handle.net/11129/3703.

35. gardenigloo.com., n.d. *Untitled.* [viewed 29 July, 2021]. Available from: https://gardenigloo.com/.

36. GATTO, E., BUCCOLIERI, R., AARREVAARA, E., IPPOLITO, F., EMMANUEL, R., PERRONACE, L. & SANTIAGO, J.L., 2020. Impact of Urban Vegetation on Outdoor Thermal Comfort: Comparison between a Mediterranean City (Lecce, Italy) and a Northern European City (Lahti, Finland). *Forests.* **11**(2), pp. 228 DOI 10.3390/f11020228.

37. GEHL., 2020. *Public Space & Public Life during COVID 19.* Gehl. [viewed 5 January 2021]. Available from: https://covid19.gehlpeople.com/files/report.pdf.

38. GEHL., 2021. *Public Space, Public Life, and COVID 19 In the first phases of the reopening in Denmark.* [viewed June 15, 2021]. Available from: https://covid19.gehlpeople.com/files/report_phase2.pdf.

39. GEMINIDATALOGGERS., 2019. *Tinytag Plus 2 Temperature Logger for Thermistor Probe (-40 to +125°C)TGP-4020* . Tiny Tag. [viewed May 10, 2021]. Available from: http://gemini2.assets.d3r.com/pdfs/original/3747-tgp-4020.pdf.

40. GEORGATOU, C.&KOLOKOTSA, D., 2016. Urban climate models. In: D. KOLOKOTSA and M. SANTAMOURIS eds., *Urban climate mitigation techniques* London ; New York: Routledge.

41. GONZALEZ, A., 2021. *Untitled.* [viewed January 5, 2021]. Available from: https://www.instagram.com/p/CNoBj81jvyd/?utm_source=ig_embed.

42. GREEN LAHTI., n.d. *Lahti European Green Capital 2021.* n.d., [viewed 25 February 2021]. Available from: https://greenlahti.fi/en.

43. GREEN LAHTI., n.d. *Environmental-Themed Skating Rink For Lahti Market Square.* [viewed July 28, 2021]. Available from: https://greenlahti.fi/ymparistoteemainen-luistelukentta-lahden-torille.

44. GROAT, L. & WANG, D.D., 2013. *Architectural research methods.* Second edition ed. New York, NY: Wiley.

45. HELGE. ‚Questions about simulating in winter conditions, 2017. 15 May,. Available from: http://www.envi-hq.com/viewtopic.php?f=3&t=3851&p=13093&hilit=snow&sid=0790274e26a0d0a1b2ee522e4c9573a0#p13093.

46. honaronline.ir., 2017. *Mobile Theater Trailer returns to underprivileged areas.* Iran: [viewed 29 July, 2021]. Available from: http://www.honaronline.ir/Section-performance-3/101885-mobile-theater-trailer-returns-to-underprivileged-areas.

47. IPCC., 2014a. *Climate Change 2014 Synthesis Report.* Genova, Switzerland: IPCC. Available at: https://www.ipcc.ch/site/assets/uploads/2018/05/SYR_AR5_FINAL_full_wcover.pdf. (Accessed: January 5, 2021).

48. IPCC., 2014b. Urban Areas. In: *Climate Change 2014 – Impacts, Adaptation and Vulnerability: Part A: Global and Sectoral Aspects*, pp. 535-612. Available at: http://dx.doi.org/10.1017/CBO9781107415379.013. (Accessed: January 5, 2021).

49. JOHANNES, K. & SAMRIT, L., 2020. Regional Climate Change Scenarios for the Water Management in Lahti and Mikkeli. *Geological Survey of Finland Environmental Geology Unit Espoo.* Available from: http://tupa.gtk.fi/raportti/arkisto/61_2019.pdf.

50. JOHANSSON, E., 2016. Urban thermal comfort in the tropics. In: *Urban climate challenges in the tropics*. Singapore: World Scientific Publishing Co. Pte. Ltd.

51. KARTTA.LAHTI.FI., 2019. *Land use in Lahti.* 19 May, [viewed 28 July, 2021]. Available from: https://kartta.lahti.fi/ims/fi/Map.

52. KESTREL., n.d. *Product Specifications for Kestrel Weather Meters, Model Numbers 1000-3550.* n.d., [viewed March 25, 2021]. Available from: https://kestrelinstruments.com/mwdownloads/download/link/id/23/.

53. KIM, S., SINCLAIR, V.A., RÄISÄNEN, J. & RUUHELA, R., 2018. Heat waves in Finland: present and projected summertime extreme temperatures and their associated circulation patterns: HEAT WAVES IN FINLAND. *International Journal of Climatology.* **38**(3), pp. 1393-1408 DOI 10.1002/joc.5253.

54. LAHTI., n.d. *Kauppatori.* Available at: https://e-asiointi.lahti.fi/docs/eTapahtuma/05_kauppatori.pdf (Accessed: June 5, 2021).

55. LAHTI., 2017. *KYSELY LAHDEN KESKUSTASTA Raportti karttakyselyn tuloksista.* Available at: https://docplayer.fi/70159210-Kysely-lahden-keskustasta-raportti-karttakyselyn-tuloksista.html (Accessed: June 5, 2021).

56. LAHTIGUIDE.FI., n.d. *History of Lahti.* n.d., [viewed 28 July, 2021]. Available from: http://www.lahtiguide.fi/lahti/history-of-lahti/?lang=en.

57. LAITINEN, A., 1975. *Torilla 1975.* Lahti: Laitinen Anja Available from: https://albumitauki.fi/item/mDDs6FRwWSNG.

58. LENZHOLZER, S., KLEMM, W. & VASILIKOU, C., 2018. Qualitative methods to explore thermo-spatial perception in outdoor urban spaces. *Urban Climate.* **23**, pp. 231-249 DOI 10.1016/j.uclim.2016.10.003.

59. LENZHOLZER, S. & VAN DER WULP, N.,Y., 2010. Thermal Experience and Perception of the Built Environment in Dutch Urban Squares. *Journal of Urban Design.* **15**(3), pp. 375-401 DOI 10.1080/13574809.2010.488030.

60. LIN, T., 2016. Management of Shading and Public Places. In: R. EMMANUEL ed., *Urban climate challenges in the tropics* London: Imperial College Press, pp. 49-78.

61. MADDEN, K. & PROJECT FOR PUBLIC SPACES., 2001. *How to turn a place around.* 2. printing ed. New York, NY: Project for Public Spaces.

62. MADSEN, S.H.J. & HANSEN, T., 2019. Cities and climate change - examining advantages and challenges of urban climate change experiments. *European Planning Studies.* **27**(2), pp. 282-299. Available from: http://www.tandfonline.com/doi/abs/10.1080/09654313.2017.1421907 DOI 10.1080/09654313.2017.1421907.

63. MAHAROOF, N., EMMANUEL, R. & THOMSON, C., 2020. Compatibility of local climate zone parameters for climate sensitive street design: Influence of openness and surface properties on local climate. *Urban Climate.* **33**, pp. 100642 DOI 10.1016/j.uclim.2020.100642.

64. MARTINELLI, L., LIN, T. & MATZARAKIS, A., 2015. Assessment of the influence of daily shadings pattern on human thermal comfort and attendance in Rome during summer period. *Building and Environment.* **92**, pp. 30-38 DOI 10.1016/j.buildenv.2015.04.013.

65. MATZARAKIS, A., MAYER, H. & IZIOMON, M.G., 1999. Applications of a universal thermal index: physiological equivalent temperature. *International Journal of Biometeorology.* **43**(2), pp. 76-84. Available from: https://doi.org/10.1007/s004840050119

66. MATZARAKIS, A., RUTZ, F. & MAYER, H., 2007. Modelling radiation fluxes in simple and complex environments—application of the RayMan model. *International Journal of Biometeorology.* **51**(4), pp. 323-334. Available from: https://www.ncbi.nlm.nih.gov/pubmed/17093907 DOI 10.1007/s00484-006-0061-8.

67. METEOBLUE.COM., 2021. *Lahti, Finland.* [viewed 29 July, 2021]. Available from: https://www.meteoblue.com/en/weather/historyclimate/climatemodelled/lahti_finland_649360.

68. MILLS, G., 2016. Integration of Climate knowledge in Urban Design and Planning. In: M.R. EMMANUEL ed., *Urban climate challenges in the tropics* London: Imperial College Press, pp. 335-355.

69. Ministry of Agriculture and Forestry., 2014. *Finland's National Climate Change Adaptation Plan 2022.* Finland: Ministry of Agriculture and Forestry.

70. Ministry of the Environment and Statistics Finland., 2017. *Finland's Seventh National Communication under the United NationsFramework Convention on Climate Change.* Ministry of the Environment and Statistics Finland.

71. MYRICK,P., 2020. *The Recovery Will Happen in Public Space.* May, [viewed 5 January 2021]. Available from: https://www.pps.org/article/the-recovery-will-happen-in-public-space?fbclid=IwAR3hovB-NtqsLkJwc7uZjF7GR3obJaJhTLD-l49iahHrpyK-WULrhBpJm2s.

72. NÄYHÄ, S., 2007. Heat mortality in Finland in the 2000s. *International Journal of Circumpolar Health; Int J Circumpolar Health.* **66**(5), pp. 418-424 DOI 10.3402/ijch.v66i5.18313.

73. NOURI, A.S., 2015. A Framework of Thermal Sensitive Urban Design Benchmarks: Potentiating the Longevity of Auckland's Public Realm. *Buildings (Basel).* **5**(1), pp. 252-281. Available from: https://search.proquest.com/docview/1672885895 DOI 10.3390/buildings5010252.

74. NOURI, A. & COSTA, J.P. Placemaking and climate change adaptation: new qualitative and quantitative considerations for the "Place Diagram".

75. NOURI, A.S., LOPES, A., COSTA, J.P. & MATZARAKIS, A., 2018. Confronting potential future augmentations of the physiologically equivalent temperature through public space design: The case of Rossio, Lisbon. *Sustainable Cities and Society.* **37**, pp. 7-25 DOI 10.1016/j.scs.2017.10.031.

76. OKE, T.R., 1978. *Boundary layer climates.* London: Methuen.

77. OKE, T.R., MILLS, G., CHRISTEN, A. & VOOGT, J.A., 2017. *Urban climates.* Cambridge: Cambridge University Press.

78. OLIVEIRA, S. & ANDRADE, H., 2007. An initial assessment of the bioclimatic comfort in an outdoor public space in Lisbon. *International Journal of Biometeorology; Int J Biometeorol.* **52**(1), pp. 69-84 DOI 10.1007/s00484-007-0100-0.

79. PAPADOPOULOS, S., KONTOKOSTA, C.E., VLACHOKOSTAS, A. & AZAR, E., 2019. Rethinking HVAC temperature setpoints in commercial buildings: The potential for zero-cost energy savings and comfort improvement in different climates. *Building and Environment.* **155**, pp. 350-359 DOI 10.1016/j.buildenv.2019.03.062.

80. PATERSON, S.K., PELLING, M., NUNES, L.H., DE ARAÚJO MOREIRA, F., GUIDA, K. & MARENGO, J.A., 2017. Size does matter: City scale and the asymmetries of climate change adaptation in three coastal towns. *Geoforum.* **81**, pp. 109-119 DOI 10.1016/j.geoforum.2017.02.014.

81. PENG, Y., PENG, Z., FENG, T., ZHONG, C. & WANG, W., 2021. Assessing Comfort in Urban Public Spaces: A Structural Equation Model Involving Environmental Attitude and Perception. *International Journal of Environmental Research and Public Health; Int J Environ Res Public Health.* **18**(3), pp. 1287 DOI 10.3390/ijerph18031287.

82. PÉREZ-LOMBARD, L., ORTIZ, J. & POUT, C., 2008. A review on buildings energy consumption information. *Energy and Buildings.* **40**(3), pp. 394-398 DOI 10.1016/j.enbuild.2007.03.007.

83. PEURALA, J., n.d. *ESS readers long for live music and more benches and flower arrangements in Lahti Market Square.* Lahti: Available from: https://www.ess.fi/paikalliset/4131364.

84. RKY.FI., 2009. *Lahti City Hall, the market square and the ceremonial axis of Mariankatu.* [viewed 29 July, 2021]. Available from: http://www.rky.fi/read/asp/r_kohde_det.aspx?KOHDE_ID=1903.

85. ROMERO, L., SÁNCHEZ, J., SÁNCHEZ, F. & ÁLVAREZ, S., 2020. Analyzing the urban heat Island: Comprehensive methodology for data gathering and optimal design of mobile transects. *Sustainable Cities and Society.* **55**, pp. 102027. Available from: https://dx.doi.org/10.1016/j.scs.2020.102027 DOI 10.1016/j.scs.2020.102027.

86. SAARI, H.&NISKANEN, R., 2017. *KYSELY LAHDEN KESKUSTASTA. Raportti karttakyselyn tuloksista.* Available at: https://docplayer.fi/70159210-Kysely-lahden-keskustasta-raportti-karttakyselyn-tuloksista.html (Accessed: June 5, 2021).

87. SANTAMOURIS, M., 2015. Analyzing the heat island magnitude and characteristics in one hundred Asian and Australian cities and regions. *The Science of the Total Environment.* **512-513**, pp. 582-598. Available from: https://www.ncbi.nlm.nih.gov/pubmed/25647373 DOI 10.1016/j.scitotenv.2015.01.060.

88. SANTAMOURIS, M., 2016. Urban warming and mitigation Actual status, impacts and challenges. In: M. SANTAMOURIS and D. KOLOKOTSA eds., *Urban climate mitigation techniques* Abingdon, Oxon ;: Routledge.

89. SANTAMOURIS, M., 2006. *Environmental design of urban buildings.* 1. publ. ed. London [u.a.]: Earthscan Available from: http://www.loc.gov/catdir/toc/ecip0614/2006016809.html.

90. SANTOS NOURI, A. & COSTA, J.P., 2017. Placemaking and climate change adaptation: new qualitative and quantitative considerations for the "Place Diagram". *Journal of Urbanism.* **10**(3), pp. 356-382. Available from: http://www.tandfonline.com/doi/abs/10.1080/17549175.2017.1295096 DOI 10.1080/17549175.2017.1295096.

91. SUOMI, J. & KÄYHKÖ, J., 2012. The impact of environmental factors on urban temperature variability in the coastal city of Turku, SW Finland. *International Journal of Climatology.* **32**(3), pp. 451-463. Available from: https://doi.org/10.1002/joc.2277

92. SUOMI, J., 2018. Extreme temperature differences in the city of Lahti, southern Finland: Intensity, seasonality and environmental drivers. *Weather and Climate Extremes.* **19**, pp. 20-28. Available from: http://dx.doi.org/10.1016/j.wace.2017.12.001 DOI 10.1016/j.wace.2017.12.001.

93. SUOMI, J. & KÄYHKÖ, J., 2012. The impact of environmental factors on urban temperature variability in the coastal city of Turku, SW Finland. *International Journal of Climatology.* **32**(3), pp. 451-463. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1002/joc.2277 DOI 10.1002/joc.2277.

94. THORSSON, S., HONJO, T., LINDBERG, F., ELIASSON, I. & LIM, E., 2007. Thermal Comfort and Outdoor Activity in Japanese Urban Public Places. *Environment and Behavior.* **39**(5), pp. 660-684 DOI 10.1177/0013916506294937.

95. THORSSON, S., LINDBERG, F., BJÖRKLUND, J., HOLMER, B. & RAYNER, D., 2011. Potential changes in outdoor thermal comfort conditions in Gothenburg, Sweden due to climate change: the influence of urban geometry. *International Journal of Climatology.* **31**(2), pp. 324-335 DOI 10.1002/joc.2231.

96. THORSSON, S., LINDQVIST, M. & LINDQVIST, S., 2004. Thermal bioclimatic conditions and patterns of behaviour in an urban park in Göteborg, Sweden. *International Journal of Biometeorology; Int J Biometeorol.* **48**(3), pp. 149-156 DOI 10.1007/s00484-003-0189-8.

97. TIMEANDDATE.COM., 2021. *2021 Sun Graph for Lahti.* [viewed 29 July, 2021].

98. Toivonen Seppo, 1901. *Lahden tori 1910-luvulla.* Lahti: Toivonen Seppo Available from: https://albumitauki.fi/item/9uK5ePusmDuQ.

99. TOMLINSON, C.J., CHAPMAN, L., THORNES, J.E. & BAKER, C.J., 2011. Including the urban heat island in spatial heat health risk assessment strategies: a case study for Birmingham, UK. *International Journal of Health Geographics.* **10**(1), pp. 42. Available from: https://www.ncbi.nlm.nih.gov/pubmed/21682872 DOI 10.1186/1476-072X-10-42.

100. Umbrella Sky Project., 2021. *Untitled.* [viewed 5 January 2021]. Available from: https://www.facebook.com/UmbrellaSkyProject/photos/4745441258805939.

101. WHYTE, W.H., 1980. *The social life of small urban spaces.* tenth printing, october 2012 ed. New York, NY: Project for Public Spaces.

102. WILLENS, K., 2005. *In this Saturday, Feb. 12, 2005, pedestrians walk beneath Christo and Jean-Claude's "The Gates," in New York's Central Park.* NY: [viewed 28 July,

2021]. Available from: https://www.ny1.com/nyc/all-boroughs/news/2020/05/31/christo--artist-known-for-massive--fleeting-nyc-displays--dies.

103. YAN, C., GUO, Q., LI, H., LI, L. & QIU, G.Y., 2020. Quantifying the cooling effect of urban vegetation by mobile traverse method: A local-scale urban heat island study in a subtropical megacity. *Building and Environment.* **169**, pp. 106541. Available from: http://dx.doi.org/10.1016/j.buildenv.2019.106541 DOI 10.1016/j.buildenv.2019.106541.

104. YANG, B., OLOFSSON, T., NAIR, G. & KABANSHI, A., 2017. Outdoor thermal comfort under subarctic climate of north Sweden – A pilot study in Umeå. *Sustainable Cities and Society.* **28**, pp. 387-397. Available from: https://dx.doi.org/10.1016/j.scs.2016.10.011 DOI 10.1016/j.scs.2016.10.011.

105. YILMAZ, S., KÜLEKÇI, E.A., MUTLU, B.E. & SEZEN, I., 2021. Analysis of winter thermal comfort conditions: street scenarios using ENVI-met model. *Environmental Science and Pollution Research International; Environ Sci Pollut Res Int.* DOI 10.1007/s11356-020-12009-y.

106. ZEČEVIĆ, M., 2017. Installation: Between the Artistic and Architectural Project. *AM Časopis Za Studije Umetnosti i Medija; AM Journal of Art and Media Studies.* (12), pp. 55-70 DOI 10.25038/am.v0i12.167.

107. ZHANG, L., ZHAN, Q. & LAN, Y., 2018. Effects of the tree distribution and species on outdoor environment conditions in a hot summer and cold winter zone: A case study in Wuhan residential quarters. *Building and Environment.* **130**, pp. 27-39. Available from: https://dx.doi.org/10.1016/j.buildenv.2017.12.014 DOI 10.1016/j.buildenv.2017.12.014.

Appendix

1. Interview To Anne Karvinen-Jussilainen

City Architect – Lahti City Council

January 15th, 2021

Milagros: How is the Market Square managed and organised?

Anne: Timo is the host of the marketplace; he organises every event. He also defines the location of the tents and the commercial agreements with the participants. The city council nowadays does not have enough personnel to take care of these things. It is better to have an external body in charge of it. Timo is an entrepreneur; he has an agreement with the city council where he rents and takes care of the marketplace. The period length is because he needs to evaluate the Market Square's activities financially in the long period and if it is profitable to him.

Timo has been doing an excellent job. He has good ideas; he has been doing many things with young people. Unfortunately, last year was terrible; everybody is hoping he gets through the challenges that Covid has brought. Some big happenings, like concerts, are significant for the profits, but they were not possible.

Most of the Market Square is included in Timo's agreement, except for the stairs that connect the plaza to the underground parking lot. The city takes care of the waste. He also has a storage and an office there.

M: Please, describe the Market Square.

A: The marketplace is divided into two areas, marked by an imaginary line between City Hall and the Church of *Ristinkirkko*. The east part is intensively used; we called it "the everyday area". It is where mainly the tents are located. The west area is where the concerts occur, and currently (winter), there is an ice rink. The area is empty during most of the year, which I think is very sad. There is a water and electricity supply on the west side, which is generally used when there are concerts. The installations were made when we added an underground parking lot in the square.

The division of the Market Square is evident. Most people think it is empty; I believe it is because there are not many activities on the westside.

M: Inkeri Määttä (city's Event Director) told me there is an issue with the surface of the Market Square during winter, because the underground parking lot might be heating the floor, making it very slippery.

A: Yes, it can be slippery. Also, the Market Square has a 2 meters difference, being higher in the East part. The slope is not visible because of the length of the area. When we install the ice rink, we need to make the surface even by putting sand.

We have thought a lot about the marketplace's surface material, but it has a national historical value. The area is listed in the national valuable built environments (Rakennettujen Kulttuuriympäristöjen-RKY) and covers the City Hall, *Ristinkirkko church,* and the Market Square, which is in the middle. Therefore, the decisions are from Lahti and the National Board (part of the Ministry of Education and Culture). We cannot include extensive interventions, but we manage to put a huge Christmas tree every year. Radical changes, like having some green areas, are also limited.

M: I was reviewing some of the projects for the European Green Capital 2021 in Lahti. I found a project that includes plant modules that can be moved. So, I think those kinds of "temporary interventions" can help to improve the place.

A: We have tried to put flower boxes around the city. It is very nice, and people like it! On the other hand, Timo does not like them because, during the monthly market event (1st Wednesday of each month), the boxes need to be relocated. These events are fantastic! People from around Finland come to sell their products, which is popular among Lahti citizens'. The whole marketplace and the streets nearby are full of people, and there are plenty of commercial tents and food trucks. Timo needs to move the flower boxes so that people can walk. We have a discussion every summer about the topic. I hope you can get some idea that can be more permanent.

When the monthly market is not there, the marketplace needs them! They are essential. But, it is also understandable that Timo wants to have as many sellers as he can.

M: Who develops the flower boxes?

A: Lahti city council owns them. The team of parks and green areas makes them.

M: I am interested in the city's urban planning process. Do you usually have in your design or decision-making process any climate change mitigation or adaptation approach?

A: Yes, we have different stations around the city that measures climatic conditions and air quality. There is a pollution measuring station in the city centre, and in *Rautakartano* it measures other local climate features. Finnish Meteorological Institute owns them.

In the marketplace, the wind plays a vital role because it is in the valley of two hills. Most buses lines cross the area, so pollution is also an issue. We work together with the city council team that takes care of the environments and the climate in which Johana Saarola works.

M: As a citizen, can you help me define the Market Square in winter and summer?

A: During summers, there are coffee places, fresh vegetables, and flowers shops in the market. There are much more people; there is always somebody going there. The restaurant that surrounds the market also open their terraces. You can even find summer clothes! It is nice to walk there.

During winter, it is mostly empty, and there are not many happenings. The coffee tents are mostly closed, but the indoor places remain open. Every year, the square is more and more empty than before, and it is not just for corona. Younger market sellers do not come in winter, and citizens do not go for that reason. Also, the Christmas tree gives an atmosphere to the city.

In the summertime, you just enjoy going and seeing the selling points and the possibility of having a coffee. It is a pleasant experience that you do not get anywhere else.

M: It might require something to attract them then.

A: Everybody thinks we need to build a market hall in the middle of the Market Square. They say we need a roof, an indoor area during wintertime. We have the ice-skating rink during winter, but we would like to have ideas of what else we can implement. At the end of November, we were going to open a Christmas village, like in other years, but we could not because of corona.

We hope this market does not die like in other places.

M: What has happened in other sites?

A: Well, now they just have coffee shops, but without selling places. Lahti Market Square is exceptionally big, compared to other Finnish cities. In Lahti, every Wednesday of each month, a special market is organised. Sellers from around the country come on that day. Timo takes care of that very much.

2. Interview to Timo Arasola

Market Square's Host

First Interview: February 23rd, 2021

Milagros: Tell me how you became the manager of the Market Square?

Timo: 7 years ago, the city arranged a contest where you needed to present a concept for the Market Square, in the beginning we were 6 to 7 people, and at the end we were 3 finalists. The contract was initially for 2 years, so both sides could evaluate if the agreement is working. Later I had a 3-year contract. But then I told them I did not wanted a strict contract because I would like to stay here as long as I do my work good. I needed a secure business. Considering that the city was satisfied with my job, they agreed. Since then, I have an unlimited contract. When I retire, I will need to let them know a year before. I will need to train the next person, and share my phone with more than 5000 contacts, from which 500 are foreign numbers.

The previous host (before me) stopped working at the age of 72, so I still have 14 years left. I am in good health, and I love this job! So, in April I will have been here for 6 years.

M: How has the pandemic impacted in your business?

T: I have not had any additional help (employer) for 16 months. Normally, in summertime I have 1 or 2 guys helping me because it is very busy. Last year (2020) I was supposed to have 69 events, and 95% of those events cancelled. My revenue in 2019 was 285 000 euros, in 2020 it was 130 000, that is why I cannot afford any employers.

One year ago, since the pandemic, there have been new restrictive rules. I am not able to do the same events as before. During summer, there was always a concert for 3000 to 5000 people, but the organiser said that the same event now would cost double than before. This concert is not possible anymore because the people are not willing to pay 80 euros for the tickets when it was 40 euros before.

M: You have had ups and downs during all this time….

T: Mostly positive times. I have dates where all the Market Square, Aleksanterinkatu and the next square is full of vendors, with 15 to 24 flea market sellers. My contract includes the whole Market Square, Aleksanterinkatu street, Santa fe's terrace (coffee shop), and another terrace (a restaurant).

I have a monthly market which have been here since 1879 on the 1st Wednesday of every month. In summertime I had around 250 different sellers here. In most of the cases, the sellers do not want to be in one Market Square all the year or all the season. They move around different cities every day. It is very easy for them in the southern Finland because different cities have a monthly market. Tampere organises it every 1st Monday of the month, then

Tuesday it goes to Hämeenlinna, on Wednesday they come to Lahti, Thursday the market is at Kouvola, and Friday at Helsinki. It is a tradition, but Lahti was the starter of it.

The main events are from half of April till half of October. During the summer there are 3 different cafeterias in three big tents which remain almost all the season. There is also a grill van and a waffle cafe. We also have vegetables and berries sellers, and they sell a lot. I need to put two of them for creating competition between them, if not costumers complain.

There are two permanent cafeterias (buildings), my contract includes one of them. There is another flower store (glass) in the corner. I also have other places that are all year around, like Frappua (van coffee shop) and a special flower shop which have been here for 55 years. It is opened every day! It seems like it is not supposed to be here. The city council the museum people love that! They think everything should look like it.

M: What is you relation with Lahti City council?

T: I have a contract with them, so I have control of this place. I also know what they want. When someone new comes here, I check the materials of the tents and if they are clean. There are also health inspections, but I have not had problems because I am very strict.

On the other hand, the city has around 3000 employees so every week I talk with someone different, Kokolahti or the event manager, because we need to coordinate. Kokolahti is the event's enterprise of LAHTI, and everything they do needs to be approved by the city council. They oversee the ice rink during winter.

M: Is Kokolahti or LAHTI organising any special event for this summer?

T: This year considering the Green Lahti (EGC) they will come many times: a big stage, a showroom, information points. They are mentioning doing it on 11th of May. It will be an important event, with important names.

M: Do you have a calendar for all the events of the year?

T: Yes, I do! I also have several records from previous years. We have hosted events like the Independence Day parade or the Christmas village. The distribution of the sellers changes all the time. Some Saturdays, if it is note busy, some cars come and just open their trunk to sell 2nd hand items, I ask 15 euros per car.

M: Are sellers mostly locals from the region?

T: During the monthly market, they come from around Finland. In summer we have international sellers that come from Italy, Norway, Russia, etc.

M: How do you decide the distribution of the tents?

T: On the monthly market days, there are sellers that are regulars, and they have a fixed spot. They call me if they will not come, and then I can put someone else. My phone rings all the time. I ask them if they have been here before and what so they sell, then I decide where I can put them. For example, there are special spots who sells fried fish (Muikku ja muusi). (They are a must-have if your come to the market!) I need to have those here because the smell attracts people. But I also need to allocate them away from the people who sell clothes. So, might put them next to the one who sell candies or sausages. I also have a limit of spots per activity, e.g. I can only have 7 persons who sell fish. Other activities include potatoes, juices, fishes, sausages, clothes, underwear, and cafes.

T: The average age of the costumers is above 50 years old. Not many young people come, maybe just for a coffee.

M: Is there any rule for the distance between the tents?

T: Before it needed to be 4m corridor for a security purpose. But, with Corona the distance needed to be 8m at the beginning, which meant lesser space for me to rent. It has been very quiet during the last year.

The sizes of the tents are mainly 2x3 and 4x4 meters.

M: What about the materials of the tents, do you ask for any specification?

T: In Helsinki, the market next to the ocean where they fixed that the tent needed to be orange. I do not think the colours are important, but they need to be clean and in a good stage. At the beginning the city council wanted a special type of tent. They also wanted that the market finishes at 3pm, but I proposed to leave the hours as long as the vendors wanted to stay. I believe that if they are selling at that time, it is not fair to close their business.

M: Why does the market has no activities at night?

T: I think people do not like it. During the night-time, the public do not want pastries or coffee, they prefer going to bars. We do not sell alcoholic beverages in the Market Square; it is a Finnish law. I have tried leaving the sellers for longer hours, but it was not successful. I can try again, but nowadays at 11pm all needs to be closed.

M: I could see that there is a huge pile of snow in the middle of the plaza, how do you manage the cleaning of the place?

T: I have an arrangement with a company who cleans the Market Square. I separate the waste between energy and mixed waste. The snow pile is there on purpose for the kids, they love playing on it! I just take remove it during the monthly market.

M: During these years, do you think that the vendors and the public has increase?

T: I think that during summer users have increase a lot. Lahti estimated that during the first Wednesday of the month, the public is about 15 000 to 20 000. It is a big meaning because they also visit restaurants, cafes, shops around the centre. It attracts people.

From Monday to Friday between 7 and 9 am, around 1 500 people cross the Market Square because there are two large schools and several bus stops. The average age that crosses the are in the morning is around 14 to 18 years old.

Some people that live in the outer side of Lahti can also tell you they have never been in the Market Square. When I ask them why, they just like where they live and do not need to come here.

M: Does the underground parking lot has impacted?

T: I think it is the best thing that happened in the centre. There are 600 places available, you can have a monthly card, like me, which is a lot more affordable than other options. It has made a significant impact because it is fully packed almost every weekend and during some monthly markets. There wouldn't be any other similar place in the centre to park all that number of cars.

There is a station for air quality, especially in summer when the temperature is high and humid and the pollution increases.

M: What does the market mean for the city?

T: It means the heart of the city. The streets next to the market and all the small shops are the veins of the city that somehow connect to the heart. People come to the market, but also to those shops. Two hundred fifty shops in the city centre also get benefited with the Market Square's activities.

Second interview: May 25th, 2021

M: Compared to previous years, how was May's monthly market?

T: The market was not as full as before; you can see it from my records. I stopped the records in February 2020 because after that, the activities were reduced.

M: What are the plans for the Market Square in the following months?

T: Restrictions are lighter, but there are still uncertainties for COVID19. In July we expect to have a concert. There will be three cafes, two large terraces with alcohol. There should be a large screen when Finland plays in the European Football Championship, but it is cancelled. It is hard to see the future nowadays.

The city of Lahti will bring two flower boxes and install a parking area for bikes with a guardian. Students from LAB university have designed a "hangout area" for the west side of

the market as a strategy for the pandemic for two months. It will be a terrace with a stage, where people could bring or order food or beverages they buy in other areas.

M: Previously, you mentioned that the commercial activities in the Market usually stop around 3pm, but I could see that there are activities after 8pm this month. Is this new, or is it normal during spring?

T: There has not been a typical Spring for the past two years. Before that, it was very normal. In Finland all depends on the weather; if it is good, everybody loves to be outside. Finland has a long winter, long autumn, and when spring and summer come, everybody wants to be outside. For the rest of the year, people prefer to be indoors. Weather also impacts the opening hours of the sellers. If it is rainy, cloudy or too windy, people do not come.

Food vendors can be open until 8 pm, but those who sell veggies just until 7 pm, and the alcohol's selling needs to stop after 6 pm as a Covid restriction. People that leave their work at 4 pm do not want to come just for 2 hours. Cafes (from the daily market) open from 6:30 am until 5:00 pm, they had tried to open until later, but it was unsuccessful. The waffle place and Cilantro prefer to start at 10 am because younger people usually gather in this area (east) around that time.

3. Online Questionnaire (English)

Market Square Thermal Comfort Seasonal Study

The following survey is part of a LAB University of Applied Science's thesis. The study aims to understand the user's behaviour in the Market Square throughout the different seasons and find its connection to thermal comfort. Your information is very important for the study and will be shared with the decision-makers. Your identity will remain confidential.

Last date for receiving answers: June 25th, 2021

* Required

1. Are you a Lahti resident? *

Mark only one oval.

- ◯ Yes
- ◯ No

2. For how long have you lived in Lahti? *

Mark only one oval.

- ◯ All my life
- ◯ More than a year
- ◯ Less than a year

3. What is your age group? *

Mark only one oval.

- ◯ Less than 18
- ◯ 18-24
- ◯ 25-39
- ◯ 40-60
- ◯ more than 60

4. Gender

Mark only one oval.

- ◯ Female
- ◯ Male
- ◯ Other
- ◯ Prefer not to say

5. How far away from the city centre you live? *

Mark only one oval.

- ◯ I live in the city centre
- ◯ Less than 1km
- ◯ 1-3 km
- ◯ 3-5 km
- ◯ 5-10 km
- ◯ more than 10 km
- ◯ I am not sure

6. According to each season, how often do you visit the Market Square? *

Mark only one oval per row.

	Never	Rarely	Often	Very often
Winter	◯	◯	◯	◯
Spring	◯	◯	◯	◯
Summer	◯	◯	◯	◯
Autumn	◯	◯	◯	◯

7. What is the range of hours that you visit the Market Square?

Mark only one oval per row.

	6am-9am	9am-12pm	12pm-3pm	3pm-6pm	6pm-9pm	9pm-12am
Winter	◯	◯	◯	◯	◯	◯
Spring	◯	◯	◯	◯	◯	◯
Summer	◯	◯	◯	◯	◯	◯
Autumn	◯	◯	◯	◯	◯	◯

8. How long do you usually stay?

Mark only one oval per row.

	15 minutes	30 minutes	45 minutes	1 hour	more than an hour
Winter	◯	◯	◯	◯	◯
Spring	◯	◯	◯	◯	◯
Summer	◯	◯	◯	◯	◯
Autumn	◯	◯	◯	◯	◯

9. What are the main reasons for visiting the Market Square? (You can tick more than one answer) *

Check all that apply.

- [ ] For its commercial activities
- [ ] For its cultural activities
- [ ] It is a safe place
- [ ] It is next to other areas I visit in the city centre
- [ ] It is a comfortable place on cold days
- [ ] It is a comfortable place on hot days

Other: ☐ _____

10. Did you know that on the 1st Wednesday of each month the Market Square has a traditional market? *

Mark only one oval.

- ◯ Yes
- ◯ No

11. Most of the year, activities in the market are usually over between 3 pm -5 pm. Would you like to have evening activities in the Market Square? *

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ I am not sure

12. Which activities would you prefer during the evening? (You can tick more than one answer)

Check all that apply.

- ☐ Food vendors
- ☐ Clothes and accessories vendors
- ☐ Restaurants
- ☐ Coffee shops
- ☐ Cultural events

Other: ☐ _____

13. Do you find enough shaded areas on a sunny day? *

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ I am not sure

14. Do you find enough wind protection on a windy day? *

Mark only one oval.

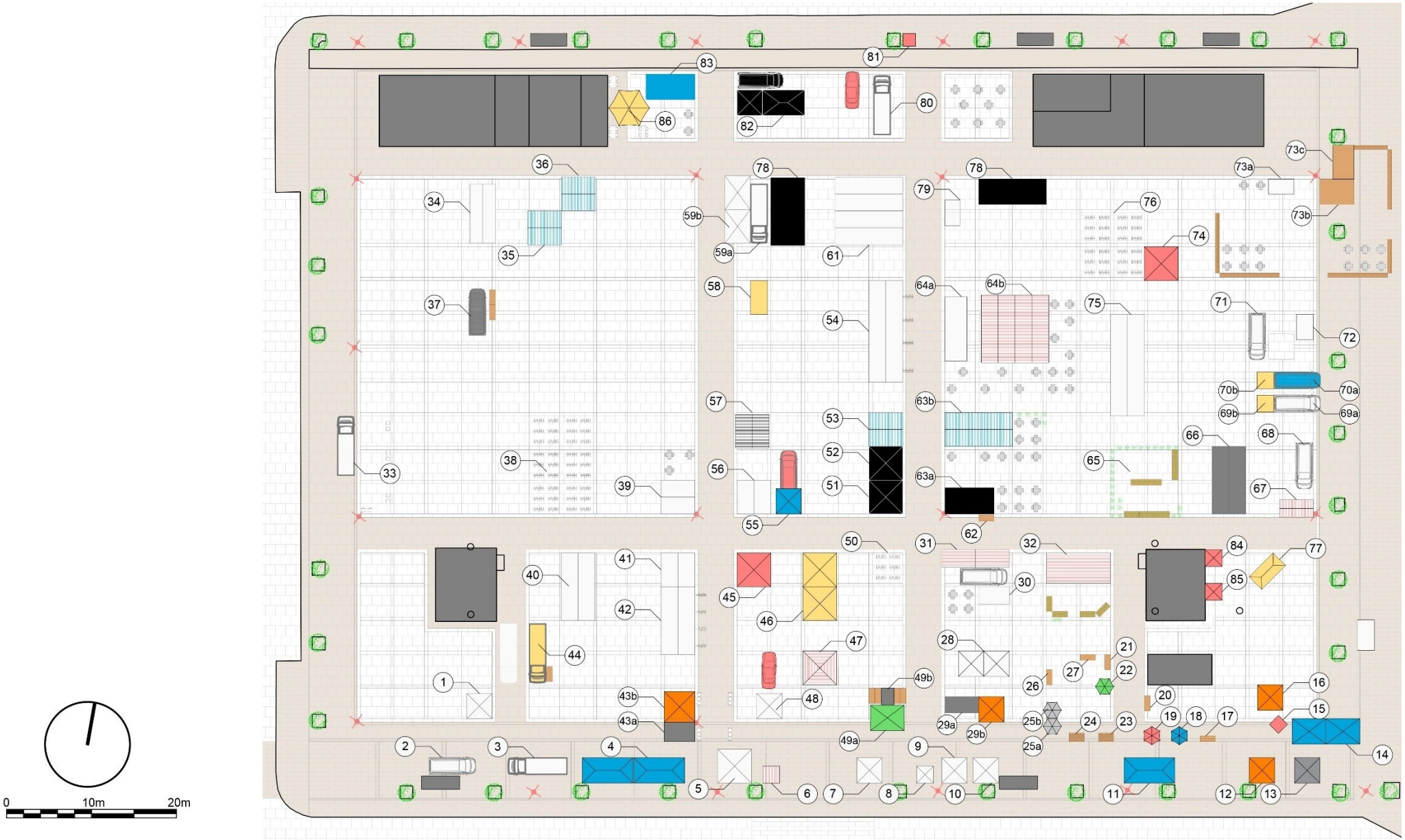
- ◯ Yes
- ◯ No
- ◯ I am not sure

15. Do you find enough rain protection on a rainy day? *

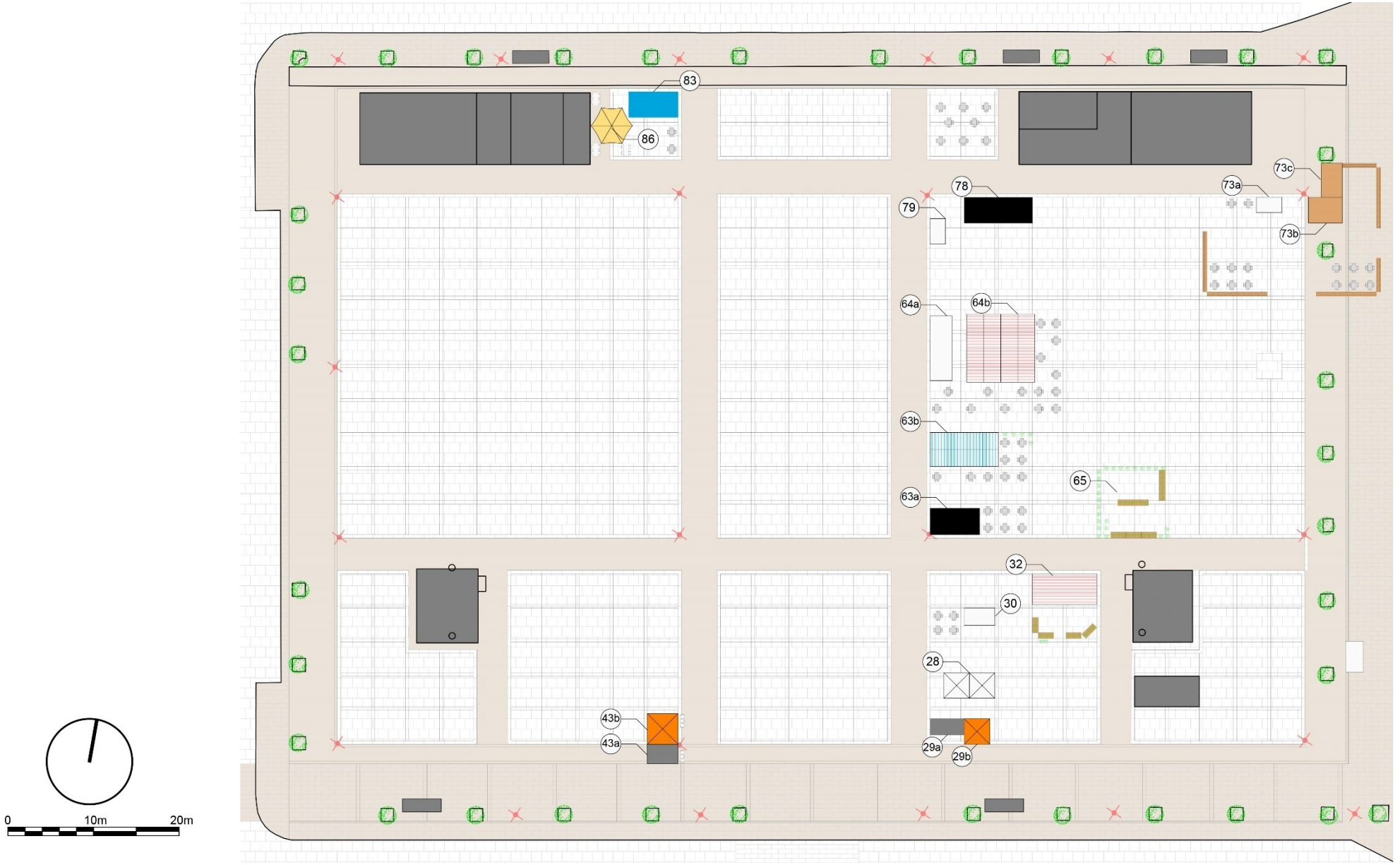
Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ I am not sure

4. Temporary Interventions- May monthly Market 2021



5. Temporary Interventions- Daily Market May 2021



6. List of May's Temporary Interventions

N	Name	Type	L	W	H	Diam.	Area	Walls	Material	Colour	Activity	Products	Comments	Monthly Market	Daily Market
1	T-Sock	Tent	3	3	2.4		9	0	Polyester and PVC	White	Clothing / Accessories	Socks		Yes	No
2	Tapolan	Vehicle	5.5	2	2.5		11	4	Metal	White	Food products/prepared food	Sausages	Retractable Sunsail	Yes	No
3	Korpel	Vehicle	8	2	2.5		16	4	Metal	White / Red	Food products/prepared food	Sausages	Lateral wall becomes a canopy	Yes	No
4	Voissa Paostetut Muikut	Tent	6	3	2.4		18	1	Polyester and PVC	Blue	Warm food (kitchen)	Fish	2 tents with same size	Yes	No
5	Muku	Tent	4	4	2.4		16	1	Polyester and PVC	White	Food products/prepared food	Candies		Yes	No
6		Tent	2	2	2.4		4	3	Polyester and PVC	White / Red	Clothing / Accessories	knitted socks		Yes	No
7	Saippuakauppias	Tent	3	3	2.4		9	2	Polyester and PVC	White	Other	Soaps and items		Yes	No
8	Maustettu Hunaja	Tent	2	2	2.4		4	3	Polyester and PVC	White	Food products/prepared food	Honey		Yes	No
9	Kerhyvan Lortsyt	Tent	3	3	2.4		9	3	Polyester and PVC	White/ Grey	Food products/prepared food	Bread and others		Yes	No
10	Soft Erikoispyyhe	Tent	3	3	2.4		9	1	Polyester and PVC	Yellow	Other	Paper towel		Yes	No
11		Tent	6	3	2.4		18	0	Polyester and PVC	Blue	Clothing / Accessories	Accerssories		Yes	No
12	Voissa Paistetut Muikut	Tent	3	3	2.4		9	3	Polyester and PVC	Orange	Warm food (kitchen)	Fish		Yes	No
13		Tent	3	3	2.4		9	1	Polyester and PVC	Grey	Food products/prepared food	Ham and Cheese		Yes	No
14	Pakastepussit	Tent	6	3	2.4		18	0	Polyester and PVC	Blue	Food products/prepared food	Candies	2 tents with same size	Yes	No
15	Viipurinrinkeleita	Umbrella / Sunsail	8	3	2.4		24	0	Polyester and PVC	Red	Food products/prepared food	Bread	Wood box with sunsail	Yes	No
16	Mithu	Tent	3	3	2.4		9	0	Polyester and PVC	Orange	Clothing / Accessories	Ethnic products		Yes	No
17		Table	1.8	0.7	1.2		1.26				Clothing / Accessories	Knitted articles and others		Yes	No
18		Umbrella / Sunsail			2.1	2.2	3.8		Polyester and PVC	Blue	Clothing / Accessories	Knitted articles and others		Yes	No
19		Umbrella / Sunsail			2.1	2.2	3.8		Polyester and PVC	Red	Clothing / Accessories	Knitted articles and others		Yes	No
20	Hunajaa	Table	1.8	0.7	1.2		1.26				Food products/prepared food	Honey	1 umbrella not in use	Yes	No
21		Table	1.8	0.7	1.2		1.26				Other	Eucalyptus branches, socks and other items		Yes	No
22	Puolukkaa	Umbrella / Sunsail			2.1	2.2	3.8		Polyester and PVC	Green	Other	Lingonberries, sockas and others		Yes	No
23		Table	1.8	1	1.2		1.8				Other	Knitted Handcrafts		Yes	No
24	Korvakorut	Table	1.8	1	1.2		1.8				Clothing / Accessories	Earings		Yes	No
25	Maarit Hyytiainen	Umbrella / Sunsail			1.2	2.2	3.8		Polyester and PVC	White	Food products/prepared food	Pastries	2 umbrellas	Yes	No

26		Table	1.8	0.7	1.2		1.26				Clothing / Accessories	Socks and others		Yes	No
27		Table	1.8	0.7	1.2		1.26				Clothing / Accessories	Knitted items		Yes	No
28	Mytajaisten Kotileipomo	Tent	6	3	2.4		18	2	Polyester and PVC	White	Food products/prepared food	Bread	2 tents of 3x3	Yes	Yes
29.a		Module	3	2	2.4		6	4	Metal	Metal	Flowers	Flowers	Lateral wall becomes a canopy	Yes	Yes
29.b		Tent	3	3	2.4		9		Polyester and PVC	Orange	Flowers	Flowers		Yes	Yes
30	Helenan Kotileipomo	Module	3	2	2.4		6	4	Metal	White	Food products/prepared food	Coffee and bread	4 tables, 1 umbrela not in use	Yes	Yes
31	Tuoretta Suomalaista Metrilakua	Tent					0				Other			Yes	No
32		Tent	8	4	2.4		32		Polyester and PVC	White / Red	Flowers	Flowers	More plants next to the tent	Yes	Yes
33	Elimaen Korikeskus	Vehicle	8	2	3		16	4	Metal	White	Other	Furniture	Lateral wall becomes a canopy, furniture next to vehicle	Yes	No
34		Tent	7	3	2.4		21		Polyester and PVC	White	Other	Rugs		Yes	No
35		Tent	4	4	2.4		16		Polyester and PVC	White / Blue	Clothing / Accessories	Clothing and others		Yes	No
36	Patty	Tent	4	4	2.4		16	2	Polyester and PVC	White / Blue	Warm food (kitchen)	Rullat		Yes	No
37	Polypussit	Vehicle	5.5	2	2.5		11	4	Metal	Grey	Other	Cleaning articles	One table next to the vehicle	Yes	No
38		Free display					0				Clothing / Accessories	Clothing		Yes	No
39	Laktoosittoma	Tent	4	4	2.4		16	3	Polyester and PVC	White / Green	Food products/prepared food	Coffee	3 tables	Yes	No
40		Tent	8	4	2.4		32		Polyester and PVC	White	Clothing / Accessories	Clothing		Yes	No
41	Taytelaku	Tent	4	4	2.4		16	1	Polyester and PVC	White	Food products/prepared food	Candies		Yes	No
42		Tent	8	4	2.4		32		Polyester and PVC	White	Clothing / Accessories	Clothing		Yes	No
43.a	Frappua	Module	2.3	4	2.2		9.2		Metal	White / Black	Food products/prepared food	Prepatation area		Yes	Yes
43.b	Frappua	Tent	4	4	2.4		16		Polyester and PVC	Orange	Food products/prepared food	Costumer's area		Yes	Yes
44	Polypussit Mustepatruunat	Vehicle	8	2	2.5		16	4	Metal	Yellow	Other	Repairing pieces	Lateral wall becomes a canopy	Yes	No
45		Tent	4	4	2.4		16		Polyester and PVC	Red	Clothing / Accessories	Clothing		Yes	No
46	Pahkinoita ja kuivahedelmia	Tent	4	4	2.4		16		Polyester and PVC	Yellow	Food products/prepared food	Dry fruits	2 tents of 4x4	Yes	No
47	Lettukahvila	Tent	4	4	2.4		16	4	Polyester and PVC	White / Red	Warm food (kitchen)			Yes	No
48		Tent	3	3	2.4		9		Polyester and PVC	White	Clothing / Accessories	Clothing		Yes	No
49.a		Tent	4	3	2.4		12		Polyester and PVC	Green	Other	CDs and other items		Yes	No
49.b		Vehicle	2	1.5	2.2		3	4	Metal	Grey	Other	CDs and other items		Yes	No
50		Free display					0				Clothing / Accessories	Clothing		Yes	No
51		Tent	4	4	2.4		16		Polyester and PVC	Black	Food products/prepared food	Vegan bakery		Yes	No

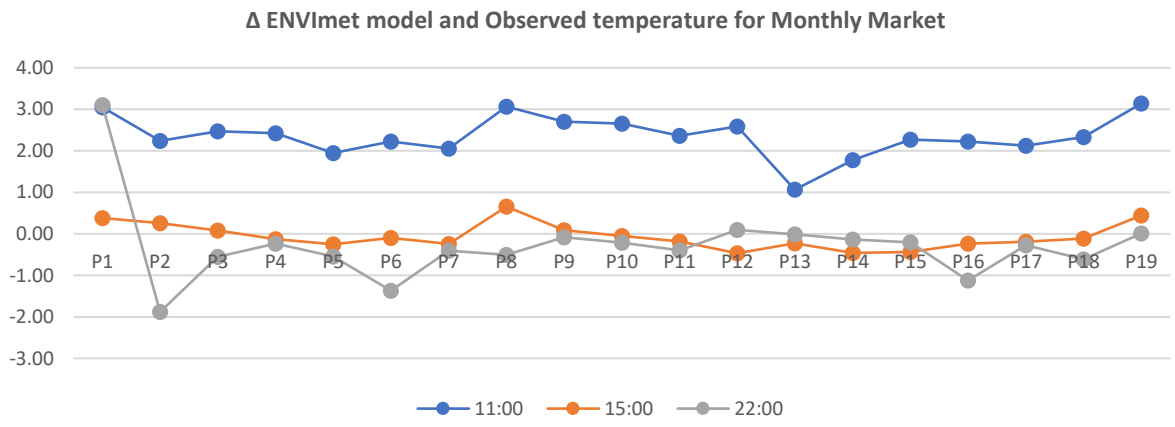
52		Tent	4	4	2.4		16		Polyester and PVC	Black	Food products/prepared food	Bakery		Yes	No
53	Suomen Vesijuoksuliitto	Tent	4	4	2.4		16		Polyester and PVC	White / Blue	Clothing / Accessories	Swimming		Yes	No
54		Tent	12	4	2.4		48		Polyester and PVC	White	Clothing / Accessories	Clothing		Yes	No
55	Lahest	Tent	3	3	2.4		9		Polyester and PVC	Blue	Clothing / Accessories	Clothing	Red van next to it	Yes	No
56	Polypussit	Tent	4	4	2.4		16	1	Polyester and PVC	White	Other	Cleaning articles		Yes	No
57		Tent	4	4	2.4		16		Polyester and PVC	White / Green	Food products/prepared food	Bakery		Yes	No
58	Alen	Module	4	2	2.5		8	4	Metal	Yellow	Food products/prepared food	Bakery	Lateral wall becomes a canopy	Yes	No
59.a		Vehicle	8	2	2.4		16		Metal	White	Clothing / Accessories	Footwear		Yes	No
59.b		Tent	4	3	2.4		12		Polyester and PVC	White	Clothing / Accessories	Footwear		Yes	No
60		Tent	8	4	2.4		32		Polyester and PVC	Green	Food products/prepared food	Dry fruits	2 tents of 4x4	Yes	No
61		Tent	8	8	2.4		64		Polyester and PVC	White	Clothing / Accessories	Clothing	2 tents of 4x8	Yes	No
62		Table	1.8	0.7	1.2		1.26				Other	Cleaning articles		Yes	No
63.a	Torikahvila ruponen	Module	3	6	2.4		18	4	Metal	White / Black	Food products/prepared food	Coffee Shop - Prepatation area		Yes	Yes
63.b	Torikahvila ruponen	Tent	8	4	2.4		32	4	Polyester and PVC	White / Blue	Food products/prepared food	Coffee Shop - Costumer's area	14 tables outside tent	Yes	Yes
64.a	Kahvipaussi	Module	8	3	2.4		24	4	Metal	White	Food products/prepared food	Coffee Shop - Prepatation area	Retractable Sunsail	Yes	Yes
64.b	Kahvipaussi	Tent	8	8	2.4		64	4	Polyester and PVC	White / Red	Food products/prepared food	Coffee Shop - Costumer's area		Yes	Yes
65	Tori Ruponen	Free display	8	8	2.4		64				Other	Flowershop	It has a structure for a tent	Yes	Yes
66	Kartanon Leipa	Tent	8	4	2.4		32	1	Polyester and PVC	Grey	Food products/prepared food	Bread		Yes	No
67	Mehuja	Tent	4	2	2.4		8	2	Polyester and PVC	White / Red	Food products/prepared food	Fruit products		Yes	No
68	Toivosen Lihansavustamo	Vehicle	5.5	2	2.5		11	4	Metal	White	Food products/prepared food	Smoked meats	Lateral wall becomes a canopy	Yes	No
69.a	Markku Santamaki	Vehicle	5.5	2	2.5		11	4	Metal	White	Food products/prepared food	Potatoes		Yes	No
69.b	Markku Santamaki	Tent	2	2	2.4		4	4	Polyester and PVC	Yellow	Food products/prepared food	Potatoes		Yes	No
70.a	Kantola	Vehicle	5.5	2	2.5		11	4	Metal	Blue	Food products/prepared food	Potatoes		Yes	No
70.b	Kantola	Tent	2	2	2.4		4	4	Polyester and PVC	Yellow	Food products/prepared food	Potatoes		Yes	No
71	Leibomo Limbbu	Vehicle	5.5	2	2.4		11	4	Metal	White	Food products/prepared food	Bakery		Yes	No
72	Aitoa Satakuntalaista Saunapalvia	Module	2	2	2.4		4	4	Wood	White	Food products/prepared food	Ham	Lateral wall becomes a canopy	Yes	No
73.a	Aitio	Module	3	2	2.4		6	4	Metal	Black	Food products/prepared food	Burgers	A box which roof's lifts when open	Yes	Yes
73.b	Aitio	Module	4	3	2.4		12	4	Wood and metal	Wood	Food products/prepared food	Bar	Costumer's area in open space, sunsail was closed	Yes	Yes
73.c	Aitio	Module	4	2.5	3		10	4	Wood and metal	Wood	Food products/prepared food	Toilets	Higher level	Yes	Yes

73.d	Aitio	Umbrella / Sunsail	4	4	3		16		Polyester and PVC	White	Food products/prepared food	Costumer's area	2 sunsails	No	No
74	Kukot	Tent	4	4	2.4		16	2	Polyester and PVC	Red	Food products/prepared food	Bread		Yes	No
75		Tent	12	4	2.4		48		Polyester and PVC	White	Clothing / Accessories	Clothing		Yes	No
76		Free display	8	8			64				Clothing / Accessories	Clothing	It has a structure for a tent	Yes	No
77	Suomalainen Hunaja	Tent	4	2	2.4		8	2	Polyester and PVC	Yellow and black	Food products/prepared food	Honey		Yes	No
78.a	Cilantro	Vehicle	8	2	2.5		16	4	Metal	Black	Warm food (kitchen)	Tacos - preparation area	Not launched yet, Lateral wall becomes a canopy	Yes	Yes
78.b	Cilantro	Tent	3	3	2.4		9	2	Polyester and PVC	Orange	Food products/prepared food	Costumer's area	2 tents	No	No
79	Waffle Café	Module	4	2	2.5		8	4	Metal	White	Food products/prepared food	Waffles	Lateral wall becomes a canopy	Yes	Yes
80	Pajuniemi Aito	Vehicle	8	2	2.5		16	4	Metal	White	Food products/prepared food	Hams and others	Lateral wall becomes a canopy	Yes	No
81	Kotileipomo Karvanen Ky	Umbrella / Sunsail	8	3	2.4		24		Polyester and PVC	Red	Food products/prepared food	Bread	Wood box with sunsail	Yes	No
82		Tent	8	3	2.4		24		Polyester and PVC	Black	Other	Baskets, wood items, and others	2 tents: 3x3 and 5x3. Black van next to it	Yes	No
83	Pinguiini Jaatelokioski	Module	6	2	2.5		12	4	Metal	Blue	Food products/prepared food	Ice cream	Lateral wall becomes a canopy	Yes	Yes
84	Perinnetuote	Tent	2	2	2.4		4		Polyester and PVC	Red	Food products/prepared food	Fish products		Yes	No
85	Aitoja Savolaisia	Tent	2	2	2.4		4	1	Polyester and PVC	Red	Food products/prepared food	Fish products		Yes	No
86		Umbrella / Sunsail			2.1	2.8	6.16		Polyester and PVC	Yellow	Food products/prepared food	Costumer's area of coffee shop		Yes	Yes
87.a		Module	2	1.5	1.5		3		Metal	Green	Food products/prepared food			No	No
87.b		Module	4	2	2.4		8		Metal	Black	Food products/prepared food			No	No
87.c		Umbrella / Sunsail			2.1	2.8	6.16		Polyester and PVC	White	Food products/prepared food		6 umbrellas	No	No
88.a	Santafe terrace	Module	4	2	2.4		8				Other			Yes	Yes
88.b	Santafe terrace	Umbrella / Sunsail			2.1	2.8	6.16				Other			No	No
89	Lahti information point	Module	8	4	3		32	4	Glass and wood	Glass and wood	Other	Information centre		No	No

7. RMSE for Monthly Market (5.05.2021)

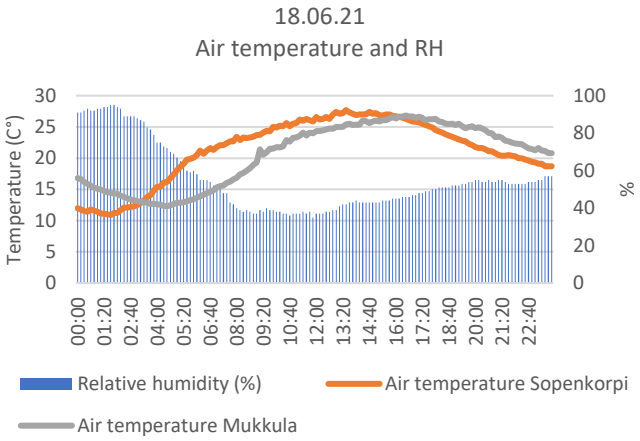
	Observed temperature			Model			Difference			Difference Square			Average	RMSE
	11:00	15:00	22:00	11:00	15:00	22:00	11:00	15:00	22:00	11:00	15:00	22:00		
P1	4.16	6.05	3.59	7.21	6.43	6.70	3.05	0.38	3.11	9.28	0.15	9.65	6.36	2.52
P2	4.44	5.89	5.48	6.68	6.15	3.60	2.24	0.26	-1.88	5.01	0.07	3.54	2.87	1.70
P3	4.36	6.08	4.06	6.83	6.16	3.51	2.47	0.08	-0.55	6.10	0.01	0.31	2.14	1.46
P4	4.02	6.27	3.85	6.44	6.14	3.61	2.42	-0.13	-0.24	5.87	0.02	0.06	1.98	1.41
P5	4.37	6.17	4.03	6.32	5.92	3.49	1.95	-0.25	-0.54	3.79	0.06	0.30	1.38	1.18
P6	4.18	6.10	4.92	6.41	6.01	3.55	2.23	-0.09	-1.37	4.95	0.01	1.88	2.28	1.51
P7	4.39	6.07	3.91	6.44	5.83	3.50	2.05	-0.24	-0.41	4.22	0.06	0.17	1.48	1.22
P8	4.54	6.11	3.80	7.60	6.77	3.29	3.06	0.66	-0.51	9.39	0.43	0.26	3.36	1.83
P9	4.22	6.09	3.48	6.93	6.18	3.40	2.71	0.09	-0.08	7.32	0.01	0.01	2.44	1.56
P10	3.92	6.08	3.67	6.58	6.03	3.46	2.66	-0.05	-0.21	7.06	0.00	0.04	2.37	1.54
P11	4.07	6.07	3.86	6.43	5.89	3.46	2.36	-0.18	-0.40	5.58	0.03	0.16	1.93	1.39
P12	3.86	6.41	3.45	6.44	5.94	3.54	2.58	-0.47	0.09	6.68	0.22	0.01	2.30	1.52
P13	5.26	6.13	3.53	6.32	5.90	3.52	1.06	-0.23	-0.01	1.13	0.05	0.00	0.39	0.63
P14	4.54	6.31	3.62	6.31	5.85	3.49	1.77	-0.46	-0.13	3.14	0.21	0.02	1.12	1.06
P15	4.15	6.25	3.61	6.42	5.81	3.40	2.27	-0.44	-0.21	5.17	0.19	0.04	1.80	1.34
P16	4.08	5.94	4.50	6.31	5.70	3.37	2.23	-0.24	-1.13	4.95	0.06	1.27	2.09	1.45
P17	4.18	5.94	3.69	6.31	5.75	3.41	2.13	-0.19	-0.28	4.52	0.04	0.08	1.54	1.24
P18	4.41	6.23	3.88	6.74	6.11	3.26	2.33	-0.12	-0.62	5.43	0.01	0.38	1.94	1.39
P19	3.56	6.01	3.46	6.70	6.46	3.47	3.14	0.45	0.01	9.86	0.20	0.00	3.35	1.83
Average										5.76	0.10	0.96		
Root Mean Square Error (RMSE)										2.40	0.31	0.98		

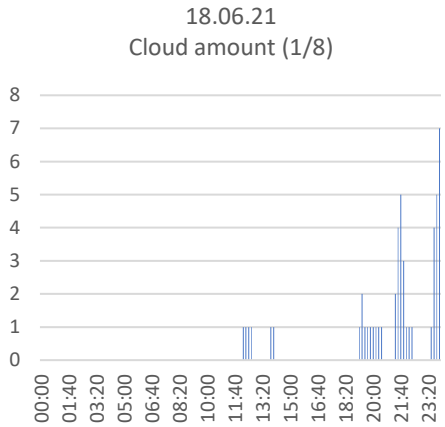
(Own elaboration, 2021)



(Own elaboration, 2021)

8. Weather and RMSE for Sunny-Clear-sky day (18.06.2021)





(Own elaboration, 2021 data retrieved from Finnish Meteorological Institute, n.d.a)

Comparison of Air Temperature in Envimet Simulations and Traverse Survey - 18.06.2021				
	Observed temperature	Model	Difference	Difference Square
Hour	19:00*	19:00	19:00	19:00
P1	27.19	23.91	-3.28	10.76
P2	26.81	23.88	-2.93	8.61
P3	27.19	23.85	-3.34	11.14
P4	28.02	23.89	-4.13	17.09
P5	27.96	23.85	-4.11	16.90
P6	30.59	23.89	-6.70	44.83
P7	27.32	23.79	-3.53	12.47
P8	26.97	23.70	-3.27	10.70
P9	28.11	23.80	-4.31	18.55
P10	30.46	23.82	-6.64	44.04
P11	27.69	23.80	-3.89	15.15
P12	28.73	23.88	-4.85	23.51
P13	27.97	23.82	-4.15	17.19
P14	28.30	23.81	-4.49	20.18
P15	27.68	23.84	-3.84	14.71
P16	28.80	23.80	-5.00	25.00
P17	27.64	23.82	-3.82	14.57
P18	27.77	23.85	-3.92	15.39
P19	27.41	23.92	-3.49	12.18
Average				18.58
Root Mean Square Error				4.31

*During that day, 19:00 represented an hour after the peak temperature.

(Own elaboration, 2021)