



Energy Efficient Design of Bus Terminals

A study of how internal loads and design choices affect the energy usage in the Nils Ericson terminal

Master of Science Thesis in the Master's Programme Structural engineering and building technology

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Department of Civil and Environmental Engineering Division of Building technology Building physics CHALMERS UNIVERSITY OF TECHNOLOGY Gothenburg, Sweden 2013 Master's Thesis 2013:102

MASTER'S THESIS 2013:102

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Cover: Photo of the Nils Ericson terminal taken by Joacim Larsson 2013.

Chalmers Reproservice/ Department of Civil and Environmental Engineering Gothenburg, Sweden 2013 **Energy Efficient Bus Terminals**

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ABSTRACT

The public transport system is in constant development, leading to construction of new bus terminal buildings. Unlike other types of buildings is research on energyefficient bus terminals relatively underdeveloped. The effect of design characteristics and design choices on energy demand of bus terminals has therefore been investigated in this thesis.

Construction of new bus terminal buildings can increase the development of its surrounding. An increased quality of the environment for waiting areas, which enclosed bus terminals contributes to, increases the quality of the entire travel which in return also leads to an increase of travelers. Toilets, controlled indoor climate and sense of security are examples affecting the environmental quality. This combined with the fact that these types of buildings handle large volumes of people makes them complex buildings and complicates an energy efficient design.

The traveler load and thereby the occupant load is the hardest parameter to define during the design of energy efficient bus terminals. This is because the amount of traveler varies widely over the day but also because the variations over the years may change significantly. The traveler load is then also strongly connected to the frequency of open and closed entrances, which affect the energy demand.

A simulation study of the Nils Ericson terminal, located in the city center of Gothenburg, was conducted in IDA ICE. Results from the study showed that the largest energy losses were caused by infiltration from entrances and poor performance on the building envelope.

Analyzes, conducted in this thesis, show that the effect of infiltration losses caused by opening of entrances affects the energy demand in greater extent than the emitted heat within the building. Revolving doors also proved to be the most efficient entrance solution but swinging doors with 90° vestibule also showed good performance. Less infiltration did cause an increased need for mechanical ventilation. With evaluations between heat gains, frequency of people and infiltration losses could a waiting hall be designed without a mechanical ventilation system and maintain comfortable indoor temperatures and CO_2 levels.

Key words: Bus terminals, energy efficient design, infiltration losses, IDA ICE, entrances, occupant load, energy modeling, swinging doors, sliding doors, revolving doors.

Energieffektiv design av bussterminaler En studie om hur internlaster och olika designval påverkar energianvändningen i Nils Ericson terminalen

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SAMMANFATTNING

Kollektivtrafiken är i ständig utveckling, vilket leder till att nya bussterminaler byggs. Till skillnad från andra typer av byggnader är forskningen för energi effektiva bussterminaler relativt outvecklad. Hur karakteristik och olika designval påverkar energiförbrukningen i bussterminaler har därför blivit undersökt i denna uppsats.

Uppförande av nya bussterminaler kan öka utvecklingen av terminalens omgivning. En ökad kvalitet på omgivande miljö för resenärer att vänta på, vilket är något förslutna bussterminaler bidrar till, ökar även kvaliteten för hela resan vilket i sin tur genererar fler resenärer. Toaletter, kontrollerat inneklimat och trygghetskänsla är exempel som påverkar kvaliteten på miljön. Detta tillsammans med det faktum att den här typen av byggnader hanterar stora volymer av människor gör dem till komplexa byggnader och komplicerar en energieffektiv design.

Belastning av resenärer och därigenom människor som befinner sig i byggnaden är den svåraste parametern att definiera under projekteringen av energieffektiva bussterminaler. Detta beror på att mängden resenärer varierar is stor omfattning under dagen men även för att variationerna över åren kan förändras avsevärt. Belastningen av resenärer är också starkt kopplad till antalet öppningar och stängningar av entréer, vilket påverkar energiförbrukningen.

En simuleringsstudie av Nils Ericson terminalen, belägen i centrala Göteborg, var utförd i IDA ICE. Studien visade att de största energiförlusterna berodde på infiltration genom entréerna och dålig prestanda på klimatskalet.

Analyser, utförda i den här uppsatsen, visar att effekterna av infiltrationsförluster till följd av öppning av entrédörrar påverkar energiförbrukningen i större omfattning än avgiven värme inifrån byggnaden. Karuselldörrar bevisade att de var de mest effektiva entrélösningarna men svängdörrar med 90° graders vestibuler visade även på en bra prestanda. Mindre infiltration resulterade i ett ökat behov av mekanisk ventilation. Men med utvärdering mellan värmetillförsel, variationer på personflöden infiltrationsförluster kan vänthallar bli designade utan mekaniska samt ventilationssystem och samtidigt bibehålla komfortabla inomhustemperaturer och CO₂ halter.

Nyckelord: Bussterminaler, energieffektiv design, infiltrationsförluster, IDA ICE, entréer, belastning av människor, energi modellering, svängdörrar, skjutdörrar, karuselldörrar.

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APPENDIX B: Variations of occupant load and schedules (C_A/C_D -values) in IDA ICE simulations

APPENDIX C: Evaluation of optimized solutions for NET

Preface

This master thesis was written as a final work of the master program *Structural engineering and building technology* at Chalmers University of technology. The thesis was written at Sweco Systems during the spring of 2013 and is partly a collaboration with a parallel master thesis written by Nicklas Karlsson MSc student at Chalmers University of technology.

Input values and characteristics during the design of energy efficient bus terminals were a relatively undescribed subject and knowledge in this area was therefore of interest for Sweco. The topic of this thesis was then further developed by discussions between Västrafik, Sweco and Chalmers.

This thesis was supervised by Angela Sasic Kalagasidis, Associate Professor in Building Physics at Chalmers University of technology, and Lars Brändemo, Energy and Environmental Coordinator at Sweco Systems. Your input and knowledge has been of great importance throughout the entire process.

A special thanks to Nicklas Karlsson for the knowledge you put into this thesis, but also for the discussions throughout the entire collaboration. The collaboration made this thesis possible!

The studied object was a complex building, were the underlying material was hard to find. Many people have for this reason been contacted and involved in the project. A special thanks to Olov Berglund at ÅF, Simon Roos at Wikström VVS-kontroll as well as employees at Västtrafik and Sweco for all your help.

Finally, big thanks to friends and family for your understanding and uplifting support.

Gothenburg, June 2013 Cajsa Lindström

Notations

Roman upper case letters

A _{temp}	Heated area [m ²].
C _A	Airflow coefficient $[m^3/m^2,S,P_a^n]$, depending on passing people per hour, N.
C _D	Discharge coefficient $[m^3/m^2, S, P_a^n]$.
Е	Energy demand during a specific time [Wh].
Einfiltration	Energy losses due to infiltration through the building envelope [Wh].
E _{solar}	Sensible energy through windows including solar radiation [Wh].
G(T _g)	Degree hours [°Ch].
Ν	[People per hour].
Ps	Pressure caused by the stack effect [Pa].
P_v	Pressure caused by mechanical ventilation [Pa].
P_{w}	Pressure caused by wind [Pa].
Q _{int}	Heat gain from internal loads [W].
Q _{leak}	Losses due to air leakages [W].
Q _{solar}	Solar heat gain [W].
Q _{tech}	Heat from technical systems [W].
Q _{trans}	Transmission losses [W].
Q _{vent}	Ventilation losses [W].
T _{indoor}	Mean indoor temperature [°C].
Tg	Limit temperature [°C].
T _u	Outdoor temperature [°C].
U (-value)	Thermal transmittance $[W/m^2K]$. Describes the insulation capacity of a window or a building element.
V_{inf}	Infiltration flow rate $[m^3/s]$.

Roman lower case letters

g (-value) Solar heat gain coefficient [-]. Indicates how much thermal radiation from the sun passes through a window.

Abbreviations

AHU	Air handling unit.
ASHRAE	The building technology society, ASHRAE, has over 50 000 members all over the world. ASHRAE preforms research in order to provide recommendations and publications on design with focus on building systems, energy efficiency, indoor air quality and sustainability.
Boverket	The Swedish national board of housing, building and planning.
CFD	Computational fluid dynamics, used to analyze flow problems.
IDA ICE	Energy calculation software for buildings.
NET	Nils Ericson terminal.
STIL	Concerted report about energy inventory of public premises with a focus on electricity use.
SVEBY	Standardisera och verifiera energiprestanda för byggnader (Translation: Standardize and verify the energy performance of buildings). Provides access to particularly user input that can be used for energy calculations.
Västtrafik	Local public transportation company for the Västra Götaland region in Sweden.

1 Introduction

This Chapter contains an introduction of this master thesis. Underlying background will initially be described followed by problem, purpose, scope and limitations for the thesis. Finally the overall methodology and outline for this thesis are described.

1.1 Background

It is today widely known that the world stands in front of the great task to reduce our energy usage. Decreases of the energy usage have for example good influence on the environment and reduce our operating costs. The building industry stands for approximately 40 % of the world's energy usage where a reduction would make a great impact (Schade, 2013).

Input values for energy design calculations are often defined with standard or recommended values. A lot of research has been made for energy efficient residential and office buildings in Sweden. Internal loads and infiltration in these types of buildings is therefore relatively easy to assume. For instance, input values from SVEBY can be used for design of office buildings and residential buildings. Energy demands for schools, healthcare premises, sport facilities and commercial premises can be compared with STIL (Swedish Energy Agency, 2011).

An increasing number of hubs in today's transport systems lead to increased construction of terminal buildings, such as bus terminals and railway stations. These buildings are characterized by high density of people in large variations, large volumes and glazed areas as well as a big focus on architectural design. Internal loads and infiltration during the operational phase in such buildings are more complicated to estimate during the design phase. Specific research of values or guidelines for energy calculations of bus terminals or terminals in general, has not been found.

The Nils Ericson terminal in the center of Gothenburg is a bus terminal building which handles large amounts of travelers every day and also has a great architectural value. The terminal uses large amounts of energy, especially district heating.

A CFD analysis made by Tsinghua University and Beijing Institute of Architecture Design, in China, shows that infiltration caused by outdoor openings can reach about 40% of a railway station's energy demand (Liu, Lin, Zhang, & Zhu, 2011). It would be of interest to see how this relates to Swedish terminal buildings, such as the Nils Ericson terminal, and climate conditions.

1.2 Problem and purpose

The purpose of the thesis is to investigate what causes high-energy demands for bus terminals, as for the Nils Ericson terminal, in Swedish climate conditions. Challenges and difficulties in the design process should be identified in order to provide appropriate assumptions and input values for energy calculations during the design process of bus terminals. The thesis is based on the following main questions:

- Are there any characteristic that defines a bus terminal useful in the design process?
- Which parameters or characteristics are difficult to estimate during the design of bus terminals?
- How much do these parameters and characteristics affect the energy demand and indoor temperature of the terminal?
- Are there any possible template values to solve these issues?
- How does the design of bus terminals vary?

The master thesis aims to establish support in the design process for energy efficient bus terminals. The thesis also aims to raise specific problematic during the design of such buildings and encourage for further research or similar work. In order to establish a reliable study, a study case has been chosen. As a result the thesis will give proposals of how the energy usage can be reduced for the studied building and how the building could have been designed today.

1.3 Scope and limitations

The thesis is based on the hypothesis that internal loads and the consequent infiltration are the cause of high energy demands for enclosed bus terminals. Occupant loads and entrance solutions are therefore the main focus in this thesis. The thesis studies primarily the heating and cooling demand for the studied object because of the complexity that occurs during energy calculations for such buildings. Scope for studies of other parameters has therefore not been possible.

The thesis is limited to only make energy calculations for one bus terminal, the Nils Ericson terminal. The study cases are limited to only concern energy efficient solutions for the waiting hall. Changes in connected zones are not considered because specific recommendations for these activities are considered to already exist. The terminal building is connected to a train station, the Central station. This is not considered in this study.

The master thesis studies the effects on indoor temperature and energy usage depending on different entrance solutions in collaboration with a parallel master thesis "Air infiltration through building entrances" written by Nicklas Karlsson, MSc student at Chalmers University of technology. Studied entrance solutions and related calculation models in the parallel master thesis are summarized and implemented in energy calculations. The parallel master thesis studies swinging and sliding doors without vestibules, with vestibules and with 90° vestibules. The thesis also studies revolving doors. No other entrance solutions were considered in this thesis.

1.4 Overall methodology and outline

The thesis consists of two parts. The first part, Chapter 2-3, contains general facts and theories for bus terminals and energy efficient design of such buildings. This part is based on literature studies and interviews.

The second part of the thesis contains a study case of the Nils Ericson terminal. Initially an energy inventory of the terminal was conducted to establish operating conditions. The studied object was then simulated in the software IDA ICE in order to create a reference model. Different design choices were simulated and compared with the reference model. Further description of the methodology for the second part of the thesis will be described in Chapter 4 and 5.



Figure 1.1. Overall methodology for the thesis.

2 Bus terminal characteristics

A bus terminal building can be described as a public transport facility which functions as a central hub in the public transport system, specifically for bus traffic. The facility should accommodate high traveler volumes and their requirements (TransLink Transit Authority, 2012).

Terminal design, whether it concerns train stations, bus terminals or airports, are based on site-specific conditions (TransLink Transit Authority, 2012). Two terminal buildings are rarely designed for the same demands or with the same conditions. The design conditions for a bus terminal are similar to airport terminals and railway stations. Terminal buildings can be a hub for different types of transportation vehicles at the same time. For instance, a terminal station can be a stop for both busses and trains. This can change the demands and design of the terminal building and thereby also the energy usage. Only bus terminal buildings will be considered further on in this thesis. Some conclusions can be considered in design of other types of terminal buildings as well even if the thesis focus on bus terminals.

Further on, will this chapter define bus terminal characteristics from a heat balance perspective. The aim of this chapter is to provide sufficient information concerning bus terminal buildings to gain an understanding of different design choices made for such building. The chapter should also give enough knowledge to follow later conducted energy calculations.

2.1 Architectural design of bus terminals

Terminal buildings can have positive effect on city development (Nätterlund & Thomasson, 2011). Construction of a new terminal building can make the surrounding area more attractive and lead to establishment of new companies and residential buildings. A new bus terminal gives a promotional value that also increases amount of travelers, approximately up to 5% (Blomquist,a, 2013).

Bus stations can be designed in many different ways. This study is limited to only concern enclosed bus terminal buildings which has regulated indoor climate. These generally consist of two main areas; a terminal hall and a bus loading area. The terminal hall usually contains passenger circulation areas, ticket booths and stores (ASHRAE, 2011).

The design of terminal buildings is strongly connected, like for most buildings, to demands and expectations for the occupants or in this case the travelers (Blomquist,b, 1992). A study made on public transport travelers shows that the environment for waiting areas is highly valued by the travelers. An increased quality of the environment for waiting areas also increases the quality of the entire travel which in return leads to an increase of travelers. Availability of toilettes and comfortable seats in an indoor environment increases the atmosphere of waiting areas significantly.

Safety is of big importance for travelers passing through terminal buildings. Presence of people in motion gives the travelers a feeling of security (Nätterlund & Thomasson, 2011). Availability of shops and cafés results in a staffed terminal during specific hours which thereby also gives a sense of security. Security guards are often needed if a terminal lacks shops or cafés. Another factor influencing the environment is lightning. Enlighten waiting areas gives a sense of increased security for the travelers, especially during dark hours. This is confirmed in Swedish regulations which states that lightning in public premises should be designed with such intensity that the occupants feel safe (Boverket, 2011). Big amount of glass in the facades also gives a secure feeling for the occupants (Nätterlund & Thomasson, 2011). Finally, orientability and architectural aspects are of great value for the travelers.

High traveler densities which can occur during rush hours require efficient flows of travelers. The sequence of movement describes a traveler's possible activities during their stay in the bus terminal (TransLink Transit Authority, 2012). First a traveler passes through an entrance, then the traveler tries to locate himself through information screens or similar. Then the traveler may purchase a ticket before walking to the correct platform or waiting area. To avoid conflicts, the terminal should, for this reason, be designed with direct communications between activities to ensure efficient flows of travelers. This sequence does not apply for all occupants in a bus terminal. Non-travelers may only be passing through or visit stores.



Figure 2.1. The sequence of movement for a traveler at a terminal building (TransLink Transit Authority, 2012).

The bus loading area and thereby the connection between platforms and the terminal building can be designed in various forms. The platforms can either be completely separated from the terminal building or be connected, e.g. docking platforms.

The principle of docked platforms means that the arriving busses dock by with the front against a building or waiting area (Nätterlund & Thomasson, 2011). This means that the bus has to reverse in order to get out. The travelers can beneficially stay inside the building until the bus has arrived if each bus stop has a separate gate. Docking platforms are most suitable for end stations of bus routes since docking and reversing takes time. Docking platforms increases the stop times and is therefore not suitable for terminals used for passing bus routes.



Figure 2.2. Examples of platform solutions. To the left: Separated platform. To the right: Docking platform (Nätterlund & Thomasson, 2011).

2.2 Heat balance of bus terminal buildings

The heat balance gives an estimated view of the heating or cooling demands in a building and describes the division of energy flow. The energy consumed within a building corresponds to energy losses and energy gains (Dahlblom & Warfvinge, 2010). The heat balance for a building is defined as Equation (2).

 $Q_{trans} + Q_{vent} + Q_{leak} = Q_{solar} + Q_{int} + Q_{tech} \quad [W]$ $Q_{trans} = \text{Transmission losses [W]}$ $Q_{vent} = \text{Ventilation losses [W]}$ $Q_{leak} = \text{Air leakages [W]}$ $Q_{solar} = \text{Solar gains [W]}$ $Q_{int} = \text{Internal loads [W]}$ $Q_{tech} = \text{Technical systems, such as heating system [W]}$ (2)

Heat gains from internal loads relate primarily to heat emitted from equipment, lights and occupants. Equipment found in a bus terminal is mainly information screens which are used to guide the travelers. Furthermore there is also ATM machines, public telephones and computers to a lesser extent. Occupant load is another important factor for the heat balance of a bus terminal building. The terminal building handles large volumes of people every day which influence the heat gain. The occupant load is further described in Chapter 2.4.

Energy losses and gains through the building envelope concerns transmission losses, infiltration losses and solar heat gain. The large traveler volumes means that entrances opens frequently which causes energy losses. Infiltration losses are further described in Chapter 2.3.

Large glass facades also have a large impact on the energy balance. Energy flows through windows depend on a large variation of parameters such as time, orientation, inclination, shading and type of window (Mata & Sasic Kalagasidis, 2009). Energy gains through windows are not only a result from direct solar irradiance but also transmission losses due to differences between indoor and outdoor climates

(ASHRAE, 2005). Temperatures and radiant emission from the sky, ground and surrounding objects does also influence the energy flow. Simplified calculations of energy flows through windows are based on the fact that these impacts correlate to outdoor temperature variations. The angle of the irradiation varies during the day which means that the amount of solar gain varies during the day. The transmission losses and heat gain through windows are therefore strongly connected to the thermal transmittance, U-value, and the solar heat gain coefficient, g-value, of the window.

A more suitable way for calculation of annual heating and cooling demands for one year is by usage of degree hours. The term degree hours can be explained by an outdoor temperature dependent thermal power summarized over time when a specific requirement is fulfilled, for example annual heating demand (Jensen, 2008). Degree hours are the amount of hours when the requirement is fulfilled during the specific time. Equation (3) and (4) defines degree hours and how a specific energy demand is calculated.

$$G(T_g) = \sum_{0}^{8760} (T_g - T_u) dt \qquad T_g > T_u \quad [^{\circ}Ch]$$

$$G(T_g) = \text{Degree hours } [^{\circ}Ch]$$

$$T_g = \text{Limit temperature } [^{\circ}C]$$

$$T_u = \text{Outdoor temperature } [^{\circ}C]$$
(3)

 $E = Q \cdot G(T_g) \quad [Wh]$ E = Energy demand during a specific time [Wh] Q = Conductance [W/K](4)

The outdoor temperature varies over the day and the year. A simplified way of estimating the degree hours are by usage of duration diagrams which are developed by sorting the outdoor temperatures from low to high temperatures during a year (Jensen, 2008). With this curve can the degree hours for a certain requirement easily be estimated by the area between the requirement and the outdoor temperature. Figure 2.3 illustrates the method of duration diagram.



Figure 2.3. By sorting the outdoor temperature from low to high values can a duration diagram be created.

2.3 Infiltration through the building envelope

Infiltration occurs in all buildings with varying extent. Unintentional gaps or outdoor openings in the building envelope can cause undesired air currents (ASHRAE, 2011). These can have negative effects on the energy demand, thermal comfort, moisture convection and air quality (Sandberg & et al., 2007). Increased energy usage due to infiltration can be a result of air entering the insulation and reduces the thermal resistance. Air currents directly in to the building increase the amount of uncooled or unheated outdoor air which must be compensated by the technical systems in order to maintain the temperature set points in the building. Infiltration can cause cold surfaces and draught which decreases the thermal comfort for the occupants. Unfiltered air can carry odors and particles which gives poorer air quality. Lastly, a high infiltration rate can reduce the function of the ventilation system. The thesis will further on only concern energy losses due to infiltration.

Airflows around the building envelope are the driving force for both intentional and unintentional air flows, i.e. ventilation and air leakages (Hagentoft, 2001). These airflows can be created by wind pressure, temperature differences and mechanical ventilation components which influence the heat and mass balance of building components. Equation (5) describes the relation between the driving forces and the total air pressure over the building envelope. The infiltration flow rate is depending on a discharge coefficient C_D , the area of the opening and the pressure difference between outdoor and indoor environment. The basic equation for infiltration flow rate is shown in Equation (6).

 $\Delta P = \Delta P_w + \Delta P_s + \Delta P_v \qquad [Pa] \tag{5}$ $\Delta P_w = \text{Pressure difference due to free wind [Pa]}$ $\Delta P_s = \text{Pressure difference due to the stack effect [Pa]}$ $\Delta P_v = \text{Pressure difference due to mechanical ventilation [Pa]}$

$$\dot{V}_{inf} = C_D \cdot A \cdot \Delta P^n \qquad \left[\frac{m^3}{s}\right]$$

$$\dot{V}_{inf} = \text{Infiltration flow rate } [m^3/s]$$

$$C_D = \text{Discharge coefficient } [m^3/m2, S, P_a^n]$$

$$A = \text{Area of entrance opening } [m^2]$$

$$\Delta P = \text{Pressure difference between indoor and outdoor } [Pa]$$
(6)

2.3.1 Air leakages through different entrance solutions

Reference for this chapter is the parallel master thesis "Air infiltration in building entrances" written by Nicklas Karlsson. The aim of the chapter is to summarize important knowledge from his work in order to understand energy calculations conducted later on. Considered entrance solutions used for this study are swinging, sliding and revolving doors.

Sliding doors are a common entrance solution for terminal buildings. Both sliding and swinging doors can be operated manually or automatic. This thesis will only include automatic doors. Both door types can be designed with a vestibule, either a straight or a 90° vestibule. A vestibule gives the opportunity for one door to close before the next one opens. This will reduce the infiltration losses. However, high flows of people can lead to a completely open passage.

Swinging doors are common solutions when a small volume of people passes. Advantages with swinging doors are, besides high air tightness during closed state, that they have flexible operation and a high base security. Disadvantages of swinging doors are that they have a low accessibility and that they can be dangerous if operated wrongly. Swinging doors is also negatively affected by large pressure differences which can lead to difficulties for opening.

An advantage with sliding doors is that they have high accessibility. Sliding doors also have a high capacity of the amount of people passing through the entrance, which make them suitable for terminal buildings. They are in contrast to swinging doors able to operate during high pressure differences. A disadvantage is that sliding doors has a low base security. Sliding doors requires larger width than swinging doors as there has to be enough space during open state.

Revolving doors is an entrance solution which can be preferable for both small and large volumes of people. The design of the wings can be performed in various ways which makes it suitable for different buildings. For example, can the amount of wings vary depending on type of door. Infiltration through revolving doors occurs by pressure driven leakages through sealants and by temperature driven air exchange cause by motion. Beneficial for revolving doors is that the outdoor and indoor climates always are separated. Revolving doors are today considered as the most energy efficient entrance solution, it is though unclear in what extent.



Figure 2.4. A single swinging door, a single sliding door and a revolving door (Coral industries; Meridian doors; International revolving door company).

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The infiltration through entrances depends on type of door, pressure and temperature differences but also amount of people passing through the opening. Adjustments with respect to number of people passing through means that the discharge coefficient, C_D can be replaced with an airflow coefficient, C_A . The airflow coefficient can be calculated according to equations in Table 2.1. These equations are limited to less than 450 people per hour. Approximations have been conducted to estimate suitable equations for higher flows of people. These are shown in in Table 2.2. At 900 people per hour is the entrance considered as fully open. Fully open swinging or sliding entrances has a C_A -value of 0,62 (m³/m²,s,Pa^{0,5}). For swinging or sliding doors with 90° vestibule is the C_A -value 0,35 (m³/m²,s,Pa^{0,5}) at fully open state. Important to note is that these equations are just approximations. Further studies in this area should be conducted to ensure real equations for these flows.

ENTRANCE TYPE	$\mathbf{C}_{\mathbf{A}} \left[\frac{m^3}{m^2 \cdot S \cdot P_a^{0.5}} \right]$
Swinging doors without vestibule	$-9,0 \cdot 10^{-7} \cdot N^2 + 1,3 \cdot 10^{-3} \cdot N - 1,6 \cdot 10^{-3}$
Swinging doors with vestibule	$-5.0 \cdot 10^{-7} \cdot N^2 + 0.9 \cdot 10^{-3} \cdot N - 2.8 \cdot 10^{-3}$
Swinging doors with a 90° vestibule	$-3,0 \cdot 10^{-7} \cdot N^2 + 0,5 \cdot 10^{-3} \cdot N - 1,9 \cdot 10^{-3}$
Sliding doors without vestibule	$-7,0 \cdot 10^{-7} \cdot N^2 + 1,1 \cdot 10^{-3} \cdot N - 1,2 \cdot 10^{-3}$
Sliding doors with vestibule	$-4,0 \cdot 10^{-7} \cdot N^2 + 0,8 \cdot 10^{-3} \cdot N - 2,4 \cdot 10^{-3}$
Sliding doors with a 90° vestibule	$-4,0 \cdot 10^{-7} \cdot N^2 + 0,7 \cdot 10^{-3} \cdot N - 2,1 \cdot 10^{-3}$

Table 2.1. Equations for the airflow coefficient C_A . N is the amount of people passing through the entrance during one hour. The equations are limited for less than 450 people per hour.

Table 2.2. Equations for the airflow coefficient C_A . N is the amount of people passing through the entrance during one hour. The equations are limited for more than 450 people per hour.

ENTRANCE TYPE	$\mathbf{C}_{\mathbf{A}} \left[rac{m^3}{m^2 \cdot \mathcal{S} \cdot \mathcal{P}_a^{0.5}} ight]$
Swinging doors without vestibule	$0,2964 \cdot \ln(N) - 1,3941$
Swinging doors with vestibule	$0,1307 \cdot e^{0,0017 \cdot N}$
Swinging doors with a 90° vestibule	$0,0928 \cdot e^{0,00147 \cdot N}$
Sliding doors without vestibule	$0,2141 \cdot e^{0,00118 \cdot N}$
Sliding doors with vestibule	$0,1168 \cdot e^{0,00185 \cdot N}$
Sliding doors with a 90° vestibule	$0,155 \cdot \ln(N) - 0,7044$



Figure 2.5. Variations of C_A values for swinging and sliding doors up to 450 people per hour, N.



Figure 2.6 Estimated variations of C_A values for swinging and sliding doors over 450 people per hour, N.

2.4 Occupant load in bus terminals are a complex and uncertain parameter

High occupant loads in a bus terminal can easily result in densities of $0.3 - 0.5 \text{ m}^2/\text{person}$ (ASHRAE, 2011). The occupant flow affects the internal heat gain and the air leakages through outdoor openings, and thereby the energy demand, indoor temperature and CO₂ levels. Each occupant passes through an entrance/exit door twice which means that the infiltration rate is significantly affected. Fundamental theory of infiltration caused by entrances is described in Chapter 2.3.

A bus terminal is often used for different purposes resulting in large variations of occupant loads. The density of occupants throughout the day is therefore a very uncertain parameter (ASHRAE, 2011). Occupant loads in airports are for instance easier to estimate. Occupant loads can be estimated by studying the number of people checking in and out.

Usually, an investigation on traveler change for past and future years is made before the design of bus terminals. This investigation can be based on the population statistic from communal statistics for the relevant location (Blomquist,a, 2013). This gives a good sense of the occupant flow in the new bus terminal. Usually, the increase of travelers corresponds to the increase of population. Noteworthy is that this rule of thumb is suitable for isolated bus terminals. Bus terminals in large cities or in connection to other types of transportations have several additional factors that also influence the increase of travelers.

Occupant loads in bus terminals are sensitive to changes in the traffic, weather conditions and varieties of other factors such as those mentioned above in the Chapter 2.1. Global factors that may also affect the demands and occupancy of a bus terminal is fuel prices and climate changes (TransLink Transit Authority, 2012).

The operating time of a bus terminal is long, sometimes even 24 hours per day (ASHRAE, 2011). The load characteristic varies significantly over the operating time for bus terminals intended for public transports. An itinerary investigation made by Västtrafik shows that there is two peaks each day when most of the travelers travel. One peak occurs in the morning between 07:00 and 09:00 and one occurs in the afternoon between 15:00 and 17:00 (VTG, 2007). The variation of travelers in Gothenburg's public transport system can be assumed as shown in Figure 2.7. The percentages are based on the total amount of travelers per day. This principle can be used for estimation of openings of entrances.



Figure 2.7. Traveler variation during one weekday in Gothenburg's public transport system (VTG, 2007).

The traveler load characteristic depends on the location. Specific values regarding the studied location should be determined for reliable assumptions. For instance, the variations in Skåne have larger peaks between 07.00 and 08.00 than Gothenburg. Meanwhile the load characteristic for Linköping complies approximately with Gothenburg. Traveler load characteristic for the public transportation in Skåne and Linköping are shown in Figure 2.8 and 2.9.



Figure 2.8. Traveler variation during the day in Skånes public transport system. The diagram is expressed in percent. (Sveriges kommuner och landsting & Trafikverket, 2012).



Figure 2.9. Traveler variation during the day in Linköpings public transport system. The diagram is expressed in percent. (Sveriges kommuner och landsting & Trafikverket, 2012).

Another important factor is the variation over the week. A useful rule of thumb, according to Västtrafik, is to assume that the amount of travelers during one weekday corresponds to the amount of travelers during the weekend.

Besides the variations of travelers the waiting time for travelers is important parameter. Emitted heat per hour from occupants can be calculated by correlation between traveler variations and wait time. The waiting time by bus stop is a dependent on the frequency of busses and can be estimated according to Figure 2.10 below (Transportforskningsdelegationen, 1981).



Figure 2.10. Waiting time by bus stop is dependent on frequency of busses (Transportforskningsdelegationen, 1981).

2.5 Indoor temperature and ventilation for bus terminals

The indoor temperature of a bus terminal should satisfy both travelers and personnel. A rough comparison of temperature set points for different bus terminals in the Gothenburg area shows a common temperature set point of 15-16°C during winter conditions. Usually outdoor conditions are applied for temperature set points during summer conditions. This indicates relatively low acceptance for the indoor temperature during winter conditions and high during summer conditions.

Ventilation flows should be designed with respect to density of people, activities, moisture contributions and material emissions. The standard requirement of outdoor airflow of 0,35 l/s, m² applies for bus terminals (Boverket, 2011). Natural ventilation is suitable depending on physical characteristic of the terminal and maintenance of air quality caused by available airflows (ASHRAE, 2011).

Bus terminals should, according to ASHRAE, be designed with positive differential pressure. This is a result of difficulties to control the air balance due to many outdoor openings (ASHRAE, 2011). It is also of great importance to maintain the terminal pressurized for minimization of contaminants and odors generated by the vehicles. To obtain a good indoor temperature for above mentioned areas zoning of the terminal is required.

3 Integrated design ensures energy demands

Energy efficient design of bus terminals concerns more than understanding of the characteristics of the building. To achieve a definitive energy efficient building considerations must be taken throughout the entire building process. The aim of this chapter is to define and inform about the integrated design concept which contributes to greater guarantees of a final energy-efficient design. The concept is later discussed in relation to bus terminal buildings and conducted work for this thesis in Chapter 7.

Design decisions in early stages of the building process have the greatest potential to affect a buildings final performance. For instance, the heating demand of a building can be reduced significantly if the orientation, shape, insulation and ventilation are optimized in early stages. Early decisions have unfortunately often low consideration for energy performance of a building. These aspects are commonly not considered before the detailed design process and often results in higher additional costs. The design process can in many cases be described as sequential, where every actor is working relatively independently. This in contrast to the building process phases causes operational islands and is depended on poor communication, ineffective coordination and insolation. Different methods have been developed in response to the effects of operational islands. (Schade, 2013)



Figure 3.1. Sequential design processes creates operational islands (Schade, 2013).

One approach where it is essential to overcome these operational islands is the integrated design process, IDP. IDP can be defined as a process were all design variables, which interact with each other and are interesting for a specific goal, are considered together in early design stages and continues through the entire life cycle of the building (Lewis, 2004). IDP can also be described as a design process where the building is seen as one large system instead of several small systems.

No definite methodology of the IDP exist which means performance of an IDP is done differently for each project (Busby Perkins+Will and Stantec Consulting, 2007). Common to all IDP is that a collaborative team makes decisions together based on shared visions and goals. This requires good communication where all team members are involved early and shares a common commitment (Lewis, 2004). A shared commitment is one of the most important aspects of an IDP.

After establishment of this can specific goals be set. The goals should be measurable and performance based (Lewis, 2004). An example of a goal could be a certain rating in an environmental certification system. When the goals are set can the strategies, for achieving the goals, be developed. This usually accomplished by brainstorming where all team members participates.

After defined strategies follows actions were the strategies are implemented and ensures achievement of the goals. In addition is IDP an iterative process during the design process where all team members are involved. IDP is roughly illustrated in Figure 3.2.



Figure 3.2. Integrated design process.

4 Study case of a bus terminal

A case study of the Nils Ericson terminal, NET, has been conducted in order to investigate how different design choices and internal loads affect the energy usage, indoor temperature and CO_2 -levels of a bus terminal. The terminal was selected due to its complexity and large energy usage which was suitable for this study. This Chapter will initially give an overall description of NET. Further on an energy inventory of NET is described which will give more detailed information about NET. These results are the input values for later conducted energy calculations.

4.1 Description of the Nils Ericson terminal

NET was built in 1996 and is situated in the center of Gothenburg, Sweden. NET is connected with Gothenburg's train station. With around 500 buss departures a day, the terminal is one of the largest connections for buss traffic for the Västra Götaland region in Sweden (Dahlquist, 2013). NET is operating between 04.00-01.00 on weekdays and 24 hours a day on weekends. This results in an operating time of around 7960 hours per year which correlates a coverage ratio of 90%.

NET is also designed with a passage connecting the central station and NET. This enables transportation changes. For instance, travelers can change from bus to bus or from bus to train.



Figure 4.1. Plan view of NET. Section A-G, on the ground floor, is divided into common areas such as shopping-, passage-, waiting- and gate areas.

The terminal consists of 7200 m² where 4160 m² is heated area (A_{temp}) and is divided into eight different sections, A-H. Section A-F consists of a large hall with boarding areas, waiting areas, passage areas and shops. The basement floor in section A-F are a garage and a technical hallway located.

Section G-H consists of technical rooms on basement floor, shops on the ground floor and staff areas on the second floor. The division of the sections is shown in Figure 4.1. Further on section A-F may be referred to as the terminal building and section G-H as the office building. These buildings have different shapes, activities, building envelopes and indoor temperature. To simplify energy inventory and calculations the following subdivision were used:

- Office floor
- Waiting hall
- Shops
- Basement

4.2 Energy inventory of the Nils Ericson terminal

Energy inventories could be made for several different reasons, energy certificates is one example. The energy inventory should establish the energy distribution within the studied building. For example, the amount of energy consumed by appliances and technical systems can be studied. The inventory should also establish the air leakages through outdoor openings and internal loads from people and appliances.

An energy inventory was made for this study in order to create reliable mathematical models which are comparable to measured energy. In order to really understand the energy distribution of the building, a visit of the building has been made. The inventory is also achieved partly by studying available documents, such as:

- Architectural drawings
- Construction drawings
- HVAC drawings
- OVK protocols
- Energy certificate
- Energy and water bills
- Interviews with operating staff

4.3 **Results and conclusions from the energy inventory**

4.3.1 Building envelope

The terminal building is built with a steel frame structure covered mainly by glass both on the roof and the exterior walls. The shape of the building envelope is a curved exterior wall towards north-east and a stair-case shaped wall on the west side, see Figure 4.2 below. The glass façade has a g-value of 26% and an exterior reflection rate of 14%. Besides the glass façade the waiting hall has five roof components insulated with foam glass.



Figure 4.2. Facade drawing of NET viewed from north-west direction (Architectural drawings).

The shops are located in insulated boxes which are located both outside the terminal building and inside. The outside exterior walls are made out of wooden frame walls insulated with mineral wool. The exterior roofs, for the shop boxes, are a steel structure insulated with both mineral wool and foam glass. The shop interior walls consist of a wooden frame structure insulated with mineral wool. The office building is built with a concrete structure and is insulated with foam glass for both the exterior walls and roof.

Two types of entrance solutions are used in NET. Five entrances with sliding doors and vestibules are located in different parts of the building. Locations of entrances are shown in Figure 4.3. There are also 18 gates to access the bus platforms which consist of single sliding doors. Air curtains are installed by every gate and entrances to some shops for minimization of heat leakages.



Figure 4.3. Location of entrances and gates in NET.

4.3.2 Technical systems and indoor temperature

NET consists of areas with different functions earlier described, for instance in Figure 4.1. Each area requires different demands on the indoor temperature. Table 4.1 shows the temperature set points for each area in NET. Temperatures set points in the waiting hall are not kept all year. For instance, the indoor temperature is often below 15°C during winter conditions for the outer zones i.e. Zone A-C. See temperature measurements between April 2012 and March 2013 in Figure 4.4.

	WINTER	SUMMER
Waiting hall	+15 °C	Outdoor
Garage	+5°C	
Shops	+20 °C	Max. 25°C
Offices	+20 °C	Max. 25°C
Storage	+18 °C	

Table 4.1. Indoor temperature set points (Sandström, 1995).



Figure 4.4. Results from temperature measurements of the waiting hall between April 2012 and March 2013. The results are taken from the control computer for NET.

NET is ventilated by a heat recovery system located in the basement. The system is designed with constant air volume, CAV. The supply- and exhaust air is distributed by diffusers on floor level in the waiting hall and in the ceilings for the shops and the office areas (Sandström, 1995). Exhaust air from shops, office areas and the waiting hall goes back to the air handling unit for heat recovery. The same air is then lead to the garage. Separate exhaust fans are used for exhaust air and smoke evacuation in the garage. Exhaust fans also evacuates air from restaurants and similar.



Figure 4.5. Principle schedule for the main ventilation system in NET.

The supply air temperature in NET depends on the outdoor temperature (Stenqvist, 2013). Set points for the supply temperature is 22.0° C at an outdoor temperature of - 10.0° C, 20.3° C at 20.0° C and 17.0° C at outdoor temperatures higher than 20.0° C.

Heat is supplied mainly by a floor heating system in the entire building. Radiators and radiant heaters are used for special areas, such as offices and some shops. District cooling is used to distribute cooling through the supply air but also chilled beams and fan coils located in the shops and at the office floor. To ensure a comfortably climate in the waiting hall openable windows are installed in the ceiling. South west facing upper windows in the waiting hall opens in stages when the indoor temperature exceeds 26°C. (Stenqvist, 2013)

4.3.3 Occupant load

A rough estimation shows that around 11 000 travelers uses NET during weekdays. This means around 5500 travelers during Saturdays and Sundays. This does not take into account other occupant activities such as:

- Just passing through.
- Waiting for other transportation vehicles.
- Visiting shops or restaurants.

Notice that these values are approximate for the years 2010-2012. Differences since introduction of congestion charging in January 2013 had a large impact on amount of travelers. Applying variations of travelers according to Chapter 2.4 gives a peak of around 1500 travelers during rush-hours. Figure 4.6 shows a simplified model of the variation of travelers for NET on weekdays.



Figure 4.6. Simplified amount of travelers during weekdays for NET.

Because of the complexity of NET and the large variation of activities, the occupant load cannot be estimated only by methods shown in Chapter 2.4 and

the rough estimation above is not enough. Therefore a more detailed study of the occupant load has been conducted. The occupant load has been verified by a previously conducted study on the main entrance to NET.

The studied entrance is located on the south-west façade and is the closest to the central station and is in direction of the center of Gothenburg. The location of the studied entrance is shown in Figure 4.9. This entrance will be referred to as the south-west entrance throughout the thesis.

Measurements were made with 5-minute intervals between 07.00-09.00 in the morning and between 15.30-17.30 in the afternoon on three different dates (Agneman, 2011). The inventory showed that during rush-hour around 60% of the passing occupants walks into the building in the morning and around 75% in the afternoon. More people tend to pass through the passage during the afternoons than during the mornings. Table 4.2 below shows the summarized results of the inventory.



Figure 4.7. Location of the studied entrance.

	TOTAL	PASSING	PASSING
DATE	PASSING	OCCUPANTS,	OCCUPANTS,
	OCCUPANTS	DIRECTION IN	DIRECTION OUT
2011-02-02, morning	1819	1120	699
2011-02-02, afternoon	2573	2006	567
2011-02-10, morning	1916	1131	785
2011-02-10, afternoon	2616	2025	591
2011-02-11, afternoon	2965	2110	855

Table 4.2. The inventory of occupant flow through door number 5 shows that around 1800-1900 occupants passes through during the morning rush-hours and around 2500-3000 during afternoon rush-hours (Agneman, 2011).

The inventory shows that the amount of occupants leaving NET has larger variations of the peaks than people entering. The reason for this could be delays in the bus- or train schedules. People entering NET is not yet aware of possible delays. The total amount of people varies lightly between the different measured days. The difference could be explained by weather. The inventory shows an indication that rain and wind increases the amount of people entering and leaving NET (Agneman, 2011). The influence of the weather has not been considered further in this study. Figure 4.8 shows example of one measured day.



Figure 4.8. Number of people passing through the studied entrance between 07:00 and 9:00 and between 15:30 and 17:30 on weekdays.

4.3.4 Energy usage in the Nils Ericson terminal

NET is supplied with both district heating and cooling. The energy usage of district heating is significantly larger than the usage of district cooling. The demand of district heating is largest during December until February and varies between 140-240 MWh monthly for the years 2009-2012. During summer conditions are the demand relatively consistent and use around 10 MWh per month. The demand of district cooling is largest during July and varies between 16-23 MWh for the years 2010-2012. During winter conditions the demand goes down to around 2 MWh. Monthly energy district heating and cooling demands in NET are shown in Figure 4.9 and 4.10.



Figure 4.9. District heating demand for NET between 2009-2012 (Dahlquist, 2013).



Figure 4.10. District cooling demand for NET between 2010-2012 (Dahlquist, 2013).

According to an energy certificate conducted during 2009 did NET use 3.3 MWh as airborne electricity and 129.7 MWh for property electricity. The energy also stated a hot water demand of 26.8 MWh. The focus in this thesis has been the district heating and cooling demand, specific electricity and hot water usage has therefore not been investigated further.

A correlation of energy measurements will separate annual variations from year to year depending on "warm" or "cold" climates. A so called "Normal-year correction" (normalårskorrigering) can correct the energy usage with respect actual outdoor temperatures (Adalberth & Wahlström, 2008). This is achieved with a correction factor calculated by dividing actual heated degree days with normal degree days. Degree days is an old-fashioned concept based on a limit temperature of 17°C (Jensen, 2008). The limit temperature is fixed to 17°C due to estimated internal loads. The number of heated degree days is calculated assuming that the heating demand only appears when the average daily temperature exceeds 11°C. The actual degree days does not take temperature increase into account. These assumptions does not always conform to buildings today, especially not bus terminal buildings with completely other indoor temperature and internal loads.

Further simulations described in Chapter 5 are therefore based on a climate file specific for the year 2010. This makes simulations comparable to actual energy usages in NET.

5 Energy modeling of the Nils Ericson terminal

The aim of this chapter is to describe the methodology of the energy simulations more in detail than the earlier description. Initially is the concept of energy modeling presented and further developed specifically for this study. The chapter also describes the construction of the reference model followed by methodology for different study cases.

5.1 Meaning and methodology of energy modeling

The purpose of energy modeling is to create an abstraction of the reality by mathematical relations (Arias, 2005). Modeling creates possibilities for different investigations of variation of parameters.

The modeling process can be divided into four different stages. The first stage is to create a conceptual model of the reality. The conceptual model illustrates the relation between different input parameters and the objective. For example the indoor temperature is depended on the building envelope, outdoor climate, surroundings, infiltration, occupants, equipment, lights and HVAC systems, see Figure 5.1.



Figure 5.1. To the left: Conceptual model of indoor temperature. To the right: Development of a quantitative model (Arias, 2005).

In the second stage a quantitative model should be created based on the conceptual model. The quantitative model describes the objective with mathematical correlations. This model can be created in computer programs. The third stage in modeling is to evaluate the quantitative model in relation to the reality. Corrections and adjustments should be performed in an iterative process during this stage to obtain reliable model. Finally, results and answers questioned in the beginning of the modeling process can be answered. The sequence of the quantitative model is illustrated in Figure 5.1 above. (Arias, 2005)
A modified version of above described modeling process was used during this study. The objectives for this study were the energy demand, indoor temperature, CO_2 levels and infiltration, of the studied building.

NET is a complex building with a large variation of building envelopes, internal loads and requirements on indoor temperature. The complexity of the building made the intentional the reference models hard to create with reasonable limitations. The models took longer time to construct as reliable models. Simplifications have been made, which will be described further in this chapter. The difference between the intentional and actual modeling processes are shown in Figure 5.2.

Two quantitative models were created and developed during this study. One of the models was created by hand calculations based on the fundamental theories in Chapter 2. The model was built up in Excel and is based on monthly average climate data and duration. The total energy usage in the model was evaluated against measured energy usage. The hand calculations aimed at establishing a perception of the energy distribution and confirm energy simulations in IDA ICE. Initially they served that purpose but the complexity of the building made this process time consuming.

The second quantitative model, hereafter referred to as the reference model, was created in the energy simulation program IDA ICE. This model aimed at establishing a more detailed perception of the objectives. Further parameter studies were performed by developments on the reference model. Summarized the hand calculation model was a support in the construction of the reference model.



Figure 5.2. To the left: The initial idea of the modeling process for the thesis. To the right: The actual modeling process for the thesis.

5.2 Description of IDA ICE

IDA ICE (Indoor climate and Energy) is computer based simulation software were indoor temperature and energy demands of buildings can be simulated. IDA ICE is used for detailed evaluations of building constructions preferably during the design phase and is today a more common tool for engineers.

In IDA ICE, a mathematical model of the studied building can be created. The building can be modeled with different zones were climate demands, ventilation demands and building envelopes can be defined for each zone in the building. Many types of studies can be performed in the software. For example the daylight, heating demand, cooling demand, solar gains and so on can be studied.

An advantage with modeling in IDA ICE is that the software can take variations in internal loads during the day into consideration. Schedules for equipment, occupants, lights and opening of doors and windows can be modeled in the software. These advantages were essential in this study.

5.2.1 Entrance settings in IDA ICE

Entrances can be created in IDA ICE models and the frequency of opening can be controlled by schedules. The software does not give opportunity to choose type of entrance door though (Karlsson, 2013). Modification of the door schedules can trick the software to overcome this limitation for sliding and swinging doors. The C_D-value is fixed to 0.65 $[m^3/m^2, S, P_a^n]$ in IDA ICE. Division of C_A with C_D gives a new factor which can be used in the schedule for the specific door. New door types can in this way be selected by applying a C_A/C_D-value in the door schedule. C_A are calculated according to equations in Chapter 2.3.1.

Applying revolving doors in IDA ICE is more complicated. In this study has the revolving door been simulated with a local air handling unit containing only supply and exhaust fans without any temperature decrease. The air exchange is then controlled by the temperature difference between indoor and outdoor climates and a user schedule. The air handling unit should correspond to infiltration losses caused by motion. Except AHU is an additional leakage linked to the zone controlled by pressure differences corresponding to leakages through the seals of the door.

This chapter only briefly describes the used methods for entrance settings, this in order to give a sufficient understanding of how difference entrance solutions can be implemented in IDA ICE. Since the methods are developed in the parallel master thesis are they more detailed described in the related report.

5.3 Development and simplifications of the reference model

The reference model was created with input parameters based mainly on the energy inventory. Results from the energy inventory are presented in Chapter 4.3. Other assumptions or simplifications are presented in this chapter.

The initial idea with the reference model was to create a building envelope close to the reality. This was possible in IDA ICE but the energy simulation times for one year were to long with respect to this thesis extent and simplifications had to be made. Figure 5.3 show the detailed model.



Figure 5.3. The detailed model of NET had a simulation time over 9 hours.

The detailed model involved many small building components such as windows and exterior doors. Reduced number of windows decreased the simulation time significantly. A simulation time of around 1 hour for a simulation of one year were accomplished. Reductions of the small building components lead to changes of the building envelope. The simplifications are visually showed in Figure 5.4. Further on it was shown that internal loads and other specifications the model increased the simulation time even more, up to 2.5 hours.



Figure 5.4. The reference model was simplified in order to minimize the simulation time.

Concerning the building envelope five main simplifications were made. Like stated above a reduction of building components such as windows and entrances had to be made in order to keep a reasonable simulation time. The 18 gates were therefore modeled as one large opening with corresponding area. The north-east façade was modeled with only one inclination for the same reason. And the south-west staircase façade was modeled with three steps instead of six. Openable window area was kept. Finally, the shop boxes were simplified to three boxes all placed inside the terminal building. Compensation of their insulated building envelope was made in the terminal façade. The boundary for this thesis was to only concern NET and not the attached central station. Therefore the connected building was modeled as a large shade. The intersection between the buildings was modeled without transmission losses. The reference model was also divided into 18 zones were indoor temperature demands were specified for each zone. The division of zones within the building is shown in Figure 5.5-5.7.



Figure 5.5. Division of zones on basement floor in the reference model.



Figure 5.6. Division of zones on ground floor in the reference model.



Figure 5.7. Division of zones on second floor in the reference model.

Chapter 4.3.1 described the construction different building components in NET. Uvalues used for the reference model are based on those constructions. After simplification and construction of the reference model was the following U-values used, see Table 5.1.

BUILDING ELEMENT	U-VALUE [W/m ² K]				
Glass facade	1,65				
Terminal roof	0,20				
Exterior shop wall	0,37				
Exterior shop roof	0,12				
Interior shop wall	0,39				
Interior shop ceiling	0,25				
Exterior office wall	0,41				
Exterior office roof	0,45				
Floor (without floor heating)	1,01				
Foundation	2,15				
Basement wall	2,66				

Table 5.1. Thermal transmittance for building elements in NET.

The occupant load was the most uncertain parameter. The traveler load, which was representative for the gate opening, was set to 11000 people with variation as shown in Figure 4.5. This did not correlate to measures of number of people performed on the south-west gate. A correlation of 42% of the pass-troughs was therefore set for the entrances. The occupant load in the building had a correlation of 20%. These correlations should approximately be representative for non-travelers in NET. Based on investigations conducted during the design phase of NET, 65% of the occupants are assumed to use the south-west entrance. The other 35% was evenly distributed over the remaining entrances. The occupancy is presented more in detail in Appendix B.

Assumptions on technical systems effectiveness were made in order to correlate with actual energy usages. Used effectiveness in the reference model was set to 70%. Effectiveness on the air curtains was assumed to be 50%.

Since NET was built in 1996 was regulations according to The Swedish National Board of Housing, Building and Planning apply from 1994. This stated that a the average infiltration should not exceed 1,6 $l/s,m^2$ at a pressure difference of ±50 Pa (Boverket, 1996). This was used for the reference model. Other input values concerning infiltration including entrance usage schedules, C_A/C_D -values, based on the occupant loads are summarized in Appendix B. More detailed description of input parameters and settings of the reference model are described in Appendix A.

5.4 Description and methodology of study cases

The simulation studies investigated how different design choices affect and user input affected the reference model. The study was executed through several different study cases with different variations. Each study case was compared against the reference model and thereby evaluated in terms of energy usage, indoor temperature CO_2 levels. Since each study case involves different variations of input parameters are different resulting parameters out of interest for each study case. Specific studied parameters for each study cases that have been conducted. Figure gives an overview and summarizes the different studies.

	Total	Total	T _{indoor}	Б	Б	CO ₂
	Heating	Cooling	(waiting hall)	\mathbf{L}_{solar}	Linfiltration	(waiting hall)
Reference model	Х	Х	X	Х	Х	X
Entrance study	Х	Х			Х	
Occupant study	Х	Х	X		X	X
Orientation study	Х	Х		Х	Х	
Ventilation study	Х	Х	X			X
Building envelope study	Х	Х	X	Х		
Ideal solution study	Х	Х	Х	Х	X	Х

Table 5.2 Studied parameters for the different study cases.

5.4.1 Variation of occupant load

The occupant load and thereby the frequency of people passing through entrances is an uncertain parameter that could change from year to year. A study which examines how different assumptions of occupant loads affect the energy demand, indoor temperatures, infiltration and CO_2 levels have been performed. This effect has been studied by variation of occupancy and thereby C_A/C_D -values. Initially variations of the traveler load were tested. The variations was kept but the daily traveler load was changed between 11 000, 15 000, 20 000, 30 000 and 40 000 travelers per day.

Further on, studies of the occupant schedules were tested. The reference model was based on periodic variations according to Chapter 2.4. Applying these schedules for each hour could be rather time consuming and other schedules were therefore investigated. This study aimed to also investigate the impacts of step change schedules and constant mean schedules. Figure 5.8 shows the studied schedules for this study.



Figure 5.8. Studied schedule types.

5.4.2 Alternative entrance solutions

A study of how different entrance solutions affect the energy demand and infiltration of the waiting hall has been conducted. This part of the energy simulations is carried out in cooperation with the parallel master thesis. The study is based on theories and methods summarized in Chapter 2.3 and 5.2.1. For swinging and sliding door solutions new C_A/C_D -values has been calculated. These are presented in Appendix B.

Initially the south-west entrance was studied since it is the busiest entrance. Based on estimations made during the preparatory stage of NET, 65% of the occupants are assumed to use the south-west entrance. Simulations were conducted were all earlier described types of entrances were tested on the studied entrance with maintained settings as for the reference model, see Chapter 2.3.1 for more detailed information of the different entrance solutions. The opening area was kept for simulations of sliding and swinging doors only the schedules were changed. The opening area was replaced with a window when the entrance was replaced with a revolving door. Window properties corresponded to other windows in NET.

Further on the gate opening was studied using the same procedure as for the southwest entrance study. Revolving doors were not simulated for all 18 gates since it is not reasonable in terms of space and costs. A reduction of gates was simulated where three revolving doors replaced the 18 gates. This was considered as a reasonable scenario if an external platform was installed and connected all de docking places for the busses. This would mean that travelers instead would, to some extent, wait outside. A shelter in the form of an external ceiling of 4 m wide was therefore applied, see Figure 5.9. Simulations were conducted with and without the exterior shelter. Finally, an ideal case study of the exterior openings was conducted by applying the most effective entrance solutions. This is more detailed described in the results.



Figure 5.9. A replacement of gate opening with three revolving doors was tested with and without an exterior roof of 4m. The exterior roof is shown in red.

5.4.3 Building envelope variations

Since NET is essentially covered with a glass façade it is of interest to investigate how the g-value, U-value and the amount of glass affect the energy demand, heat gain from solar radiation and indoor temperature. Each of these parameters was varied separately. The g-value of the windows was varied with 0.10, 0.26, 0.30, 0.35 and 0.40 and the U-vale with 0.40, 0.60, 0.90, 1.10 and 1.65 W/m²K. The amount of glass façade was then tested with 43.8, 22.7 and 17.4 % windows of the building envelope area. The different studied cases are illustrated in Figure 5.10.



Figure 5.10. Variations of amount of windows on the waiting hall envelope.

5.4.4 Changes in orientation

It is of great interest to investigate how the building reacts to different orientations. The wind varies depending on the direction which can affect the indoor temperature and the energy usage within the waiting hall. A study of how the energy demand, infiltration rate and solar energy varies dependent on rotations of 90° , 180° and 270° have been made.



Figure 5.11. NET was rotated 90° three times in order to evaluate the impact of the orientation.

5.4.5 Need for ventilation and temperature differences in the waiting hall

The design of the ventilation system in the waiting hall is interesting since both the supply and exhaust air diffusers are located at the floor level in opposite sides of the room. This study evaluates variations of the ventilation system in the waiting hall. Simulations in IDA ICE distribute the supply airflows evenly over the zone. Indoor temperature calculated in the reference model therefore contains average values for the zone. More concentrated supply flows can be created by division of the original zone with open internal walls. This study investigated how concentrated supply flows affected the energy demand, indoor temperature and CO_2 levels in the waiting hall. Other locations of the supply air can be studied the same way.

Initially the reference model was kept and tested without any ventilation in the waiting hall. The model was also tested with air recirculation and reference settings in IDA ICE. The waiting hall was then divided lengthwise into two zones, air supply zone and air exhaust zone, where no ventilation, concentrated supply airflow in north east direction, concentrated supply airflow in south west were tested. Figure 5.12 shows the division of the waiting hall into two zones.



Figure 5.12. Division of the original waiting hall zone into two separate zones.

5.4.6 Comparison of the studied cases and ideal solution

Finally, a comparison of the different study cases were conducted were the most ideal solution for NET was chosen. The ideal settings were then simulated in order to evaluate how great impact these changes would have been made on the energy demand together.

The evaluation was conducted by evaluating three criteria against each other. This resulted in a percentage of importance for each criterion. The evaluating criteria were district heating demand, district cooling demand and mean indoor temperature of the waiting hall.

Possible changes investigated in the study cases were then graded with the number 1 to the number of cases for each criterion. The highest number represented the best alternative. Lastly the score for each alternative was calculated by multiplying the score for each criterion with the earlier calculated percentage for each criterion. The total score for each alternative was then summarized and the alternative with the highest score was chosen.



5.4.7 Overview of the study cases

6 Results from the study cases

This chapter initially describes results from the energy simulation of the reference model. Since changes are only performed on the waiting hall other results that are of interest in the parameter study are only presented for the waiting hall.

Chapter 5.2 described six different study cases with different variations. Results from each study case are presented in comparison to the reference model, this in order to evaluate which parameters have the greatest impact on the energy demand of NET. The results will be presented in the same order as the over-view in Chapter 5.4.7.

Lastly a simulation of the most effective solutions was conducted in order to evaluate how low energy demands would have been possible for NET. Results from this evaluation are presented in the end of this chapter.

Results of indoor temperature in IDA ICE are based on mean values in the specific zone. The indoor temperatures in NET varies in a large extent over the year and changes are in some cases hard to illustrate with duration diagrams or similar. Results of the indoor temperature will for this reason be presented in box diagrams. The same problem occurs for CO_2 levels. These will also be presented in box diagrams. Figure 6.1 show how the results of the indoor temperature are visualized in a box diagram.

The central mark, red or blue line, in the box represents the median temperature measured during one year simulation. The edges of the box represent the 25th and 75th percentiles, i.e. temperatures between the edges stands for 50 % of the most common indoor temperatures. Lower and upper boundaries, horizontal black lines, represent the remaining values not consider as outliers. Deviating outliers are shown separately.



Figure 6.1. Temperature results are transformed into box diagrams, the right figure is a box diagram shown for the reference model.

6.1 Energy simulations of the reference model

The aim of the reference model was to create a model were the energy usage correlated to the real measurements of the studied year, 2010. Iterations were conducted and a reference model was set. A yearly simulation of the reference model resulted in a district heating demand of 1084 MWh which correlates to 89% of actual district heating demand. The reference model simulated a district cooling demand of 61 MWh which correlates to 82% of measured district cooling. Figure 6.2 and 6.3 shows monthly district heating and cooling demands in correlation to actual demands. Summarized with assumed electricity and hot water use correlates these demands to 314 kWh/m² (A_{temp}). Distribution of energy usages for the reference model is illustrated in Figure 6.4.



Figure 6.2. Simulated district heating demand in correlation to actual district heating demand.



Figure 6.3. Simulated district cooling demand in correlation to actual district cooling demand.



Figure 6.4. Distribution of consumed energy for NET considered in this study.

Energy losses due to infiltration and through windows represent the largest energy losses during winter conditions which indicate that large savings on district heating can be made in these areas. Meanwhile heat gain from windows and lightning account for most of the heat load during summer conditions which again indicates that the performance of the windows can reduce the energy usage, in this case for the district cooling demand. Figure 6.5 illustrates the distribution of energy losses for January and heat gains for July.



Figure 6.5. To the left: Distribution of energy losses in the waiting hall for January. To the right: Distribution of heat gain in the waiting hall for July.

The total amount of infiltration losses stands for 304 MWh were the largest proportion is caused by the south-west entrance, which can be seen in Figure 6.6. The south-west entrance stands for approximately 26% of the infiltration losses in the waiting hall. The other entrances stands for 32 % together which means an average percentage of 8 % per entrance. The second largest infiltration is caused by the gate opening with approximately 23%. The remaining 19% is caused by other unintentional leakages in

the building envelope. There are therefore a potential of energy savings for the southwest entrance and the gates.



Figure 6.6. Distribution of infiltration for the waiting hall.

6.2 Variation of occupant load

The occupant and traveler loads are very uncertain parameters which may vary widely during the life cycle of a bus terminal. This study intended to investigate how the building was affected by different traveler loads and assumed schedule types.



Figure 6.7. The first part of this chapter presents results when the traveller load was varied.

Initially a simulation with no occupants and closed entrances was conducted followed by simulations with 15 000, 20 000, 30 000 and 40 000 travelers per day. A comparison of the energy demands for these variations showed that an increase of travelers also increased the district heating demand but decreased the district cooling demand. Changes in district heating demands were more significant than for district cooling. For instance was the district heating demand increased with 43.47 MWh when 20 000 travelers used the terminal. Corresponding decrease of the district cooling was 4.49 MWh. For more detailed results see Figure 6.8 and 6.9.



Figure 6.8. To the left: variations of district cooling demand depended on amount of travelers. To the right: variations of district heating demand depended on amount of travelers.



Figure 6.9. The district heating demand increases significantly more than the district cooling decreases with larger amounts of travelers. Notice that the results are shown as a difference against the reference model.

The infiltration is strongly affected by increased amount of people, especially during winter conditions. Absence of occupants and thereby completely closed entrances resulted in less sensible energy losses due to infiltration. The yearly sensible energy losses increased relatively linearly with the larger amounts of travelers. For instance is the energy losses due to infiltration 307.15 MWh when 20 000 travelers uses NET. This corresponds to an increase of 13%. Figure 6.10 illustrates the energy losses due to infiltration depending on amount of travelers.



Figure 6.10. To the left: yearly energy losses caused by infiltration depending on amount of travelers. To the right: monthly energy losses caused by infiltration depending on amount of travelers.

The mean and the highest indoor temperature of the waiting hall were kept approximately the same by variation of the amount of travelers. Clear differences of the lowest indoor temperature were shown for the different variations of traveler loads. The lower boundary decreases significantly with increasing amount of travelers. Simulations also resulted in lower temperatures for the 25th and 75th percentiles when more travelers used NET. This is illustrated in Figure 6.11 below.



Figure 6.11. Indoor temperature in the waiting hall with varying amount of travelers.

The air quality of the waiting hall was negatively affected by increased number of travelers. As Figure 6.12 shows is the upper boundary increased significantly when the amount of travelers is increased. The mean levels of CO_2 also increases, but not as noticeable. Though, differences between the 25th and 75th percentile increases as well. The simulation with 40 000 travelers resulted in an upper boundary over 1 000 ppm and several more outliers than the other simulations.



Figure 6.12. Air quality in the waiting hall during depending on the number of travellers per day.



Figure 6.13. The second part of this chapter presents results when different types of schedules are used.

The occupant study also involved how different types of schedules affected the building. Simulation with step change schedules for both occupant loads and entrance openings resulted in slightly higher heating demand and slightly lower cooling demand. In percentage terms less than 1% differences were showed. Constant mean schedules affected the building in the opposite way; increased cooling demand and decreased heating demand. In percentage terms the heating demand was held within the same differential. The cooling demand did increase 4% which correlates to 2.5 MWh per year. District heating and cooling demands depending on periodic-, step change- and constant mean schedules are shown in Figure 6.14.



Figure 6.14. To the left: variations of district cooling demand depending on type of schedule. To the right: variations of district heating demand depending on type of schedule.

Type of schedule had small effects on energy losses caused by infiltration. Both step change and constant mean schedules resulted in slightly higher losses evenly distributed over the entire year, though a yearly increase of 3% at most with constant mean schedule. Figure 6.15 shows the differences in energy losses depending on used schedule type.

Resulting lower boundary of the indoor temperature in the waiting hall were affected by type of schedule. Both step change and constant mean schedules resulted in higher temperatures for the lower boundary. Moreover, there was no significant difference due to type of schedule. Figure 6.15 illustrates the resulting temperatures in the waiting hall depended on type of schedule.



Figure 6.15. To the left: Yearly energy losses caused by infiltration depending on type of schedule. To the right: Indoor temperature in the waiting hall depended on type of schedule.

6.3 Alternative entrance solutions

The energy losses in the waiting hall consist largely of infiltration through exterior openings. At the same time it is clear that the indoor temperature set point is difficult to maintain during winter conditions. A study of how different entrance solutions affect the energy demand and the thermal climate in the waiting hall has therefore been conducted. The study was performed by one study of the busiest entrance, the south-west entrance, and the gate opening. Finally three optimal solutions were developed and analyzed.



Figure 6.16. The first part of this chapter presents results when different types of entrance solutions are tested on the south-west entrance.

The simulation study of the south-west entrance demonstrated differences in infiltration losses in the waiting hall. Both types of single door solutions resulted in larger energy losses than the reference case of an entrance with sliding doors with vestibule. Single swinging doors resulted in larger energy losses than single sliding doors and lead to the worse solution, with an increase of 7.2 MWh. Swinging door solutions with vestibule also resulted in larger energy losses than corresponding entrance with sliding doors. However, sliding doors with 90° vestibule resulted in larger energy losses than corresponding entrance solution with swinging doors. The most effective entrance solution with respect to energy losses caused by infiltration was revolving doors. By replacing the current solution, sliding door with vestibule, with a revolving door the infiltration losses was reduced with 11.65 MWh. Results of energy losses due to infiltration for the studied entrance solutions are shown in Figure 6.17.



Figure 6.17. Total energy losses due to infiltration in the waiting hall for different types of entrances for the southwest entrance.

Replacements of the entrance solution for the south-west entrance showed an increased district cooling demand and decreased district heating demand due to decreased infiltration losses. Greater variations were shown for district heating than for district cooling. For instance a replacement with revolving doors increased the district cooling demand with 1.8 MWh while the district heating demand increased with 15.4 MWh. This represents a percentage increase of 1.4% and a decrease of 3.0%. District cooling and heating demand depended on entrance solution, for the south-west entrance, are shown in Figure 6.18.



Figure 6.18. To the left: District cooling demand for different entrance solutions for the south-west entrance. To the right: District heating demand for different entrance solutions for south-west entrance.

Replacement of the south-west entrance did not affect the mean indoor temperature of the waiting hall significantly. The temperatures were almost identical with the reference model. Small changes did though occur for the lowest boundary but they were barely noticeable.

	Entrance study	Single slide	Single swing	Vestibule slide	Vestibule swing	Vestibule 90° slide	Vestibule 90° swing	Revolving
ENTRANCE STUDY	Gate study	Single slide	Single swing	Vestibule slide	Vestibule swing	Vestibule 90° slide	Vestibule 90° swing	3 x revolving
	Optimal solutions							

Figure 6.19. The second part of this chapter presents results when different types of entrance solutions are tested on the opening.

The corresponding simulation for the gate opening showed similar results as the study of the south-west entrance. This resulted in lower infiltration losses for solutions with revolving doors. The study also showed that single swinging doors would have been the worse solution. The introduction of an exterior roof made a large impact though. A comparison between the infiltration losses for three revolving doors with and without the exterior roof shows a difference of 13.9 MWh. However, a solution with three revolving doors without an exterior roof still results in less infiltration losses than the reference solution. More detailed results of energy losses due to infiltration from the gate opening study are shown in Figure 6.20.



Figure 6.20. Total energy losses due to infiltration in the waiting hall for different types of entrances for the gate opening.

The district cooling and heating demand of NET changed as for the south-west entrance study. Also here the district cooling demand increased and the district heating demand decreased with increasing infiltration losses. This did not occur for the case with three revolving entrances replacing the 18 gates if an exterior shelter were added. The absence of the shelter affected the solar intake and resulted in decrease of both the district heating and cooling demand. NET consumed 60.4 MWh district cooling and 1079.0 MWh district heating with 3 revolving doors and exterior shelter. Further results of the energy demands for the gate study are presented in Figure 6.21.



Figure 6.21. To the left: District cooling demand for different entrance solutions for the gate opening. To the right: District heating demand for different entrance solutions for the gate opening.

The studied gate solutions did neither affect the mean indoor temperature of the waiting hall significantly, although extremely small changes were shown for both the boundaries and the mean temperature line.

	Entrance study	Single slide	Single swing	Vestibule slide	Vestibule swing	Vestibule 90° slide	Vestibule 90° swing	Revolving
ENTRANCE STUDY	Gate study	Single slide	Single swing	Vestibule slide	Vestibule swing	Vestibule 90° slide	Vestibule 90° swing	3 x revolving
	Optimal solutions							

Figure 6.22. The third part of this chapter presents results for three optimal entrance solutions for the waiting hall.

An evaluation of the different studied cases showed that the most effective entrance solution besides revolving doors was swinging doors with 90° vestibule. A simulation replacing all entrances, including the gate opening, with swinging doors with 90° vestibules was for this reason made. Since revolving doors seamed most efficient two simulations were conducted with this entrance solution, one when all entrances were replaced with revolving doors and one where also the gate opening was replaced with three revolving doors and an external shelter.

All three solutions resulted in less energy losses caused by infiltration. This is illustrated in Figure 6.23. The solution of which the least infiltration occurred was when all the entrances and gates were replaced with revolving doors. The reduction was then 93.4 MWh.



Figure 6.23. Total energy losses due to infiltration in the waiting hall for the ideal entrance solutions.

The largest district cooling demand occurred when only the entrances were replaced with revolving doors and when swinging doors with 90° vestibules were used. But the major effects were shown for the district heating demand. The case when revolving doors were used everywhere consumed the least district heating and the case with swinging doors with 90° vestibules the most. Noteworthy is that relatively small changes occurred between the different entrance solutions. The results of the energy demands for the ideal entrance solutions are illustrated in Figure 6.24.



Figure 6.24. To the left: District cooling demand for the most ideal entrance solutions. To the right: District heating demand for the most ideal entrance solutions.

The different ideal solutions did affect the mean indoor temperature in the waiting hall significantly. All three cases had positive affect on the boundary levels where the upper level was decreased and the lower level increased. The mean temperature did increase for all three solutions. The least variations of indoor temperature occurred for the solution with only revolving doors and exterior shelter. The results for the mean indoor temperature in the waiting hall for the ideal entrance solutions are presented in Figure 6.25.



Figure 6.25. Indoor temperature in the waiting hall for the most ideal entrance solutions.

All ideal entrance solution did increase the CO_2 levels in the waiting hall although always below 1000 ppm. Replacements with revolving doors affected the mean levels the most. Largest differences between 25th and 75th percentile were also a result of replacement with revolving doors. The highest boundary levels of CO_2 occurred when the entrances were replaces with swinging doors with 90° vestibules. This simulation also showed similar increases of the mean levels, upper and lower boundaries than replacement with revolving doors but in smaller extent. Impact of the ideal entrance solutions on the CO_2 levels are illustrated in Figure 6.26.



Figure 6.26. Air quality in the waiting hall for the most ideal entrance solutions.

6.4 Building envelope variations

Large heat loads due to solar radiation and transmission losses through windows give potential in reduction of energy demands for NET. The performance, where the gvalue and U-value of the windows were varied separately, and amount of windows were investigated.



Figure 6.27. The first part of this chapter presents results when the g-value is varied for the windows in NET.

Increasing g-values resulted in higher district cooling demands and lower district heating demands. The increased district cooling demand consisted of about half of the savings made for district heating. For instance, a g-value of 0.4 returned a district heating saving of 40.0 MWh and an increased district cooling demand of 20.3 MWh. More detailed results of district heating and cooling demands with varying g-value is shown in Figure 6.28.



Figure 6.28. To the left: District cooling demand with changes of the g-value. To the right: District heating demand with changes of the g-value.

An increased g-value also results in increased sensible heat from solar and windows which can also be the reason for decreased district heating demands. Monthly summarized heat gains and losses due to transmission and solar radiation are shown in Figure 6.29.



Figure 6.29. Sensible heat from solar and windows depending on g-value.

Variations of the g-value of the windows only affect the indoor temperature briefly. Interesting though is a clear increase of differences between high and low temperatures with increased g-value. The mean indoor temperature also increases then. The effect on the indoor temperature in the waiting hall for variations of g-value is presented in Figure 6.30.



Figure 6.30. Indoor temperature in the waiting hall with varying g-value for the windows.



Figure 6.31. The second part of this chapter presents results when the U-value is varied for the windows in NET.

Variations of the U-value resulted the opposite way compared to variations of the g-value. The district cooling demand decreased while the district heating demand increased for higher U-values. For instance, if a window with a lower U-value, such as $0.4 \text{ W/m}^2\text{K}$, would have been chosen could the district heating demand have been reduced with 188.30 MWh. The district cooling demand would then have increased with 28.79 MWh. More results concerning district heating and cooling demand due to changes of the U-value are illustrated in Figure 6.32.



Figure 6.32. To the left: District cooling demand with changes of the U-value. To the right: District heating demand changes of the U-value.

The indoor temperature in the waiting hall was also affected strongly due to changes of the U-value for the windows. Lower U-values resulted in less variation of the indoor climate but with increasing number outliers. The most noticeably was that low U-values resulted in much higher boundary temperatures. The differences between the 25th and 75th percentile decreased with lower U-values. Finally, the simulations also showed a distinct increase of the mean temperature. This is illustrated in Figure 6.33.



Figure 6.33. Indoor temperature in the waiting hall with varying U-value for the windows.



Figure 6.34. The third part of this chapter presents results when different amounts of window areas for the waiting hall are studied.

Evaluation of how NET reacts in terms of energy usage depending on amount of windows in the waiting hall resulted in large differences for the district heating demand. The district heating demand increased with 89.6 MWh when the entire waiting hall was covered with a glass façade. This correlated to 43.8% of the waiting hall envelope area compared to 28.8% of the reference case. A decrease of 77.6 MWh was achieved when all the north-east glass façade was replaced with a roof. The differences in district cooling demand did not vary in the same extent as the district heating demand. The smallest district cooling demand occurred when all the horizontal roof components applied with roof material. A decrease of 1.3 MWh was then achieved. The results of the energy demands for NET with different roof solutions are shown in Figure 6.35.



Figure 6.35. To the left: District cooling demand depended on amount of window area of the waiting hall. To the right: District heating demand depended on amount of window area of the waiting hall.

The different roof solutions did also affect the sensible heat gain through the windows in different ways. Each increase of window area resulted in larger heat gain during summer conditions and larger heat losses during winter conditions. This is illustrated in Figure 6.36.



Figure 6.36. Sensible heat from solar and windows depending on amount of windows for the waiting hall.

A final comparison of the mean temperature in the waiting hall for the different roof solutions was conducted. This showed that an increase of window area decreased the mean temperature slightly in the zone and the lower temperature boundaries. Meanwhile the upper boundary and the differences between the 25th and 75th percentile increased. Summarized were the best indoor temperatures reached for the solutions with small window areas and the worse temperatures for the solutions with large window areas. This is shown in Figure 6.37.



Figure 6.37. Indoor temperature in the waiting hall depending on amount of windows for the waiting hall.

6.5 Changes in orientation

Solar radiation as well as wind intensity changes depending on a building's orientation. The orientation of bus terminals depends on several more factors like directions of people in movement and availability. Nevertheless, it is interesting to examine how energy demands and infiltration in a building such as NET changes depending on the orientation. The reference model was rotated three times clockwise, 90°, 180° and 270°.



Figure 6.38. This chapter presents results from an orientation study.

The most affected parameter when rotating NET was the district heating demand. Simulations show that rotations of 90° and 270° would decrease the district heating demand with 17.8 MWh respective 25.1 MWh. At the same time, the simulations show that the district cooling demand increases for all rotations, at most with 9.7 MWh for a rotation of 180°. Figure 6.39 shows the results for energy demands depending on rotation.



Figure 6.39. To the left: District cooling demand depended on rotation of NET. To the right: District heating demand depended on rotation of NET.

Small changes in sensible heat from windows and exterior openings were shown with studied rotations. A rotation of 180° resulted in the largest infiltration losses with 263.4 MWh which is 37.2 MWh more than for a rotation of 90° which corresponds to the lowest infiltration of 226.2 MWh. Furthermore, the simulations also showed that a rotation of 180° give the greatest difference in sensible heat from the windows. A rotation of 90° has the greatest positive impact during summer conditions because heat from windows is then greatly reduced. This is illustrated in Figure 6.40.



Figure 6.40. To the left: Differences of sensible heat from solar and windows in comparison to the reference model. To the right: Infiltration through exterior openings depended on rotation.

6.6 Need for ventilation and temperature differences in the waiting hall

Since the infiltration of outdoor air is of great magnitude does this study examine how much energy that can be saved by turning off the ventilation system or replacing the heat recovery unit with recirculation. Further on indicates the large volumes of the waiting hall that temperature differences can occur within the zone. The waiting hall is therefore divided into two separate zone connected by an opening, see Figure 5.12. This way can the effect of switching places of the supply and exhaust air be examined as well.



Figure 6.41. The first part of this chapter presents results when waiting hall consists of one zone.

The district heating and cooling demand of NET were strongly affected by changes in the ventilation system. These are illustrated in Figure 6.42. When the ventilation system in the waiting hall was turned off both the district heating and cooling demand decreased with 102.21 MWh respectively 6.61 MWh. Replacement of the heat recovery unit against a recirculation unit resulted in a larger decrease of district heating but an increase in the district cooling demand. The district heating demand decreased with 151.59 MWh and the district cooling increased with 2.11 MWh.



Figure 6.42. To the left: District cooling demand depended on rotation of NET. To the right: District heating demand depended on rotation of NET.

The indoor temperature and CO_2 content in the waiting hall were also affected by changes in the ventilation system. When the ventilation system was turned off the upper and lower boundaries got more extreme but the mean temperature was kept. The temperatures corresponded to the reference model for the recirculation system except that the mean temperature was slightly higher. Concentrations of CO_2 increased greatly with the changes of the ventilation system. Recirculation demonstrated the worse values were the upper boundary amounted to almost 1000 ppm. Results for the indoor temperature and air quality in the waiting hall depended on ventilation changes are shown in Figure 6.43.



Figure 6.43. To the left: Indoor temperature in the waiting hall during changes in the ventilation system. To the right: Air quality in the waiting hall during changes in the ventilation system.



Figure 6.44. The second part of this chapter presents results when waiting hall is divided into two separate zones.

The initially idea was to create two really thin zones with openings to the waiting hall which should represent the supply and exhaust air. This appeared not to work in the software and a thicker division was therefore conducted. Division of the original waiting hall zone into two separate zones resulted in small differences for the district heating and cooling demand. These are shown in Table 6.1 below.

	DISTRICT COOLING [MWh]	DISTRICT HEATING [MWh]
Reference model	61,09	1 084,79
Divided model	60,46	1 086,58

Table 6.1. District heating and cooling demand for the reference model compared to the divided model.

The division of the waiting hall resulted in differences for the boundary temperatures, especially the lower boundary. Lower temperatures occur for Zone 1, i.e. the zone where the least infiltration takes place. The mean temperatures and upper boundary are not significantly affected. When the ventilation system in the waiting hall is turned off are the same differences between Zone 1 and 2 shown, slightly larger differences

for the upper boundary occurs. The lower boundaries of Zone 1 and 2 got the results if instead all the entrances and gates were constantly closed. Finally was a simulation conducted were the supply and exhaust air changed positions. No differences did then occur. Interesting temperature results for the temperature division due to division of the waiting hall zone are shown in Figure 6.45.



Figure 6.45. Differences in indoor temperature when the waiting hall is divided longwise into two zones.

6.7 Comparison of the studied cases and ideal solution

The aim of this study was to investigate how the waiting hall can be optimized without affecting the indoor temperatures. An evaluation of above presented results was conducted in order to choose the most optimized solution.

During the evaluation of the chosen criteria was the district heating demand rated as the most important factor and the mean indoor temperature as the least important factor. The percentage of importance for each criterion is presented in Table 6.2.

	Heating cons.	Cooling cons.	Indoor temp.	Sum	Corr. Sum	Procentage
Heating cons.	0	1	1	2	3	50%
Cooling cons.	0	0	1	1	2	33%
Indoor temp.	0	0	0	0	1	17%
Sum	-	-	-	3	6	100%

Table 6.2 Evaluation of criteria which resulted in a percentage of importance.

Studies evaluated for the ideal solution for NET were the entrance study, envelope study, orientation study and ventilation study. Only the last ideal entrance solutions were evaluated. Likewise were only the ventilation systems for even distribution considered. The occupant study was not evaluated in this study.

The results and conclusions of the evaluation can be seen in Appendix C. The evaluation showed that the following changes would give the most energy efficient solution for NET:

- Increased g-value for the windows to 0.4.
- Decreased U-value for the windows to $0.4 \text{ W/m}^2\text{K}$.
- All horizontal roof components without windows, 22.7% of the waiting hall envelope area.
- A rotation of 90⁰.
- No ventilation.
- Replace all entrances with revolving doors. Also replace the gate with three revolving doors and an exterior shelter.

Resulting energy demands for the optimized model were a reduction of the district heating demand with 370.2 MWh and an increase of 72.6 MWh for the district cooling demand. These results are also shown in Figure 6.46.



Figure 6.46. To the left: District cooling demand for optimized solution compared with the reference model. To the right: District heating demand for optimized solution compared with the reference model.

The indoor temperature of the waiting hall increased significantly. More controlled indoor temperatures appeared for the optimized model, were the difference between 25th and 75th percentile was a lot less. The mean indoor temperature also increased from around 21°C to 25°C. The upper temperature set point was still kept for the optimized simulation. However, lowest temperature that occurred was 20°C. More detailed results are presented in Figure 6.47.

In addition to increased indoor temperatures appeared also higher levels of CO_2 . Upper boundary of CO_2 was over 1000 ppm, meanwhile the mean indoor level also increased. Unlike the indoor temperatures did the differences in 25^{th} and 75^{th} percentile increase. Also these results are presented in Figure 6.47.



Figure 6.47. To the left: Indoor temperature in the waiting hall for optimized solution compared with the reference model. To the right: Air quality in the waiting hall for optimized solution compared with the reference model.

7 Discussion and conclusions

If analyzes, of how various solutions integrate with each other, are carried out in early stages of the building process then there is a great potential to develop more energy-efficient bus terminals in the future. Many work areas are connected to the design of bus terminal buildings. Apart from the usual actors, such as architects, civil engineers and contractors are other specialists useful. A closer collaboration like in IDP could lead to better decisions where each competence is fully utilized.

This has caught the attention several times during the work. For instance, was it initially hard to find needed information for the development of the reference model. More united documentation, which could be a result of IDP, would simplify a lot of similar work. In the search for occupant loads and variation it was clear that specialists in traffic and public transportation possessed great knowledge which was useful for the energy calculations.

The traveler's needs and demands on the terminal building are the most vital aspects in the design. This means that the design in terms of energy efficiency is not always the most prioritized aspect. With higher demands on energy usage in all types of buildings it is of great importance to give energy efficient design greater value in the design process without affecting the travelers needs and demands. On the other hand it is also of great importance for engineers to understand the importance of demands and valuations for the travelers. Increased number of traveler could also lead to energy savings, for instance lower fuel demands.

The building handles large flows of occupants and travelers varied over the day but also the years. The traveler load and thereby the occupant load is the hardest parameter to define during the design of energy efficient bus terminals. The traveler load is then also strongly connected to the frequency of open and closed entrances, which affect the energy demand. Increased number of travelers results in higher heating demands and reduced cooling demands. The effect of infiltration is in greater extent than the emitted heat within the building. This also causes lower extreme indoor temperatures and higher CO_2 levels. This is seen in the simulation study with variations of traveler loads.

The alternative entrance study shows that selection of other entrance solutions could reduce the energy demand in NET, and increase the indoor temperature. Replacement with revolving doors has proved to be most efficient but with respect to costs is it not excluded that usage of swinging doors with 90° vestibule is a good alternative in a energy saving point of view. Important to consider is that reduced infiltration causes larger CO_2 levels.

High g-values for windows reduced the energy usage without extreme temperature increases. Meanwhile was the energy demand decreased by low U-values, which also improved the indoor temperatures. This was further confirmed by decreasing the amount of windows. The sensible heat from solar and windows showed then less heat gain during summer conditions but also less energy losses during winter conditions. It
is important to evaluate the amount of glass on a façade against poorer indoor climate and larger energy demands even if large glass facades give a sense of security and an architectural value.

It does not necessarily mean that the largest infiltration losses occur in the worst wind direction. This is shown in the orientation study. In a building with large proportions of windows can the solar radiation affect the temperatures which in return affect the infiltration losses.

More than one optimized solution of NET needs to be evaluated. This since even if the most energy efficient solutions were chosen could the simulation not maintain comfortable indoor temperatures and air quality in the waiting hall. Perhaps is a lower upper set point for the indoor temperature needed. But this would however demand more cooling. Even if the CO_2 levels only rarely reach 1000 ppm does this mean that the building is sensitive to higher traveler loads, which are likely to happen during the life cycle of a terminal.

In summary, the most important conclusions are that low energy demands for bus terminals can be achieved by low U-values, high g-values, optimized orientation and well evaluated entrance solutions in the early design phase. Ventilation of a waiting hall is not always necessary but needs to be evaluated against entrance solutions and frequency of people in order to maintain comfortable indoor temperatures and CO_2 levels.

8 Other considerations and continued work

Proposals of energy saving actions presented in this thesis are not evaluated with regard to investment costs. This is of course an important factor to consider in terms of efficiency improvements on an operating building.

Seasonal and weather depended occupant loads has not been evaluated in this thesis. It is possible that less people wait inside the terminal during warm and clear weather conditions than during cold and rainy. This could lead to a decrease in occupancy during summer and an increase during winter. This could lead to an increase of both district heating and cooling demands. The thesis does neither take variations during weekends into consideration which would probably differ slightly from weekday variations. Further studies in this area could be out of interest.

Energy efficient buildings do not necessarily mean only minimized energy usages. Energy in the production of different building materials has a great influence on the environment as well. Many terminal buildings are very eye-catching and have large architectural values. It is therefore possible that environmental friendly materials are not a high priority. This has not been considered in this thesis but could be an interesting approach in further studies.

All terminal buildings are surrounded with large amount of polluted air and gases from vehicles. Further investigations on the air quality due to air leakages containing contaminants could be out of interest. Are the concentrations harmful to the occupants and especially people staying longer periods such as staff? ASHRAE recommends pressurized terminals to deal with this issue. In what extent is this considered in design of terminal buildings for Swedish conditions?

The thesis implies large energy losses due to infiltration through entrances simultaneously have the thesis only focused on indoor temperatures and CO_2 levels. High infiltration losses could indicate to uncomfortable operative temperature and thereby poor thermal climate for the travelers and personnel. This could be evaluated more.

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Appendix A: Input values in the reference model

Energy calculations conducted in this thesis were implemented in the energy simulation software IDA ICE. A reference model was created and several study cases were further conducted. Important settings and input values applied in the reference model are presented in this annex. Table 1 summarizes the U-values for the different building components. Additional settings and input values are presented in Table 2. Detailed schedules for occupants and entrances are presented in Appendix B.

BUILDING ELEMENT	U-VALUE [W/m ² K]
Glass facade	1,65
Terminal roof	0,20
Exterior shop wall	0,37
Exterior shop roof	0,12
Interior shop wall	0,39
Interior shop ceiling	0,25
Exterior office wall	0,41
Exterior office roof	0,45
Floor (without floor heating)	1,01
Foundation	2,15
Basement wall	2,66

Table1. U-values for the building components in the reference model.

Standard air handling unit



Figure 1. AHU in the reference model.

	Equipment [W/m2]	Lights [W/m2]	Occupancy [no./m2]	Heat setpoint [°C]	Cool setpoint [°C]	Air supply (min/max) [l/sm2]	Air exhaust (min/max) [l/sm2]	Open schedule weekdays	Open schedule Sunday	Open schedule Saturday	Floor heating [W]	Ideal heater [W]	Ideal cooler [W]	Windows [m2]
Tidpunkten 1	17,66	19,57	0,27	20	25	9,50	1,50	06:00-22:00	09:00-22:00	09:00-19:00	581,00	1000,00	6000,00	0,00
tidpunkten 2	8,31	11,08	0,11	20	25	0,00	0,00	06:00-22:00	09:00-22:00	09:00-19:00	377,40	900,00	2000,00	20,88
Office floor	11,42	6,52	0,06	20	25	2,25	2,75	04:00-01:00	00:00-24:00	00:00-24:01	2950,00	7000,00	20000,00	76,62
SWEBUS	4,17	5,06	0,03	20	25	2,50	2,75	07:00-17:30	09:00-15:00	09:00-18:00	1857,00	3000,00	3000,00	53,47
Terminal hallway	0,00	0,00	0,00	15	26	0,35	0,17	04:00-01:00	00:00-24:00	00:00-24:01	891,00	0,00	0,00	5,84
Control room	27,89	0,00	0,07	20	25	2,25	2,75	04:00-01:00	00:00-24:00	00:00-24:01	854,00	4500,00	10000,00	65,40
Car rent	6,42	6,10	0,07	20	25	1,40	0,97	07:30-18:00	09:00-13:00	-	799,10	7200,00	0,00	112,97
Waiting hall	1,98	5,40	0,09	15	26	0,35/0,66	0,18/0,62	04:00-01:00	00:00-24:00	00:00-24:01	45310,00	0,00	0,00	1969,40
Garage	0,00	1,64	0,00	5	30	0,00	0,00	-	-	-	0,00	0,00	0,00	0,00
Technical hallway	0,00	0,00	0,00	21	25	0,00	0,00	-	-	-	0,00	0,00	0,00	0,00
Basement 1	0,00	0,00	0,00	21	25	0,00	0,00	-	-	-	0,00	0,00	0,00	0,00
Basement 2	0,00	0,00	0,00	21	25	0,00	0,00	-	-	-	0,00	0,00	0,00	0,00
Shop 1	3,50	5,06	0,02	21	25	1,20	2,00	07:00-17:30	09:00-15:00	09:00-18:00	2220,00	2500,00	5000,00	0,00
Zone 2	0,00	0,00	0,00	21	25	0,00	0,00	-	-	-	0,00	0,00	0,00	102,70
Shop 2	118,10	9,49	0,11	21	25	1,20	1,16	09:00-18:00	09:00-18:01	09:00-18:02	2726,00	11000,00	0,00	0,00
Shop 3	95,71	17,36	0,14	21	25	1,66	1,16	07:30-23:00	07:00-23:00	07:00-23:01	3935,00	17000,00	20000,00	0,00
Zone 5	0,00	0,00	0,00	21	25	0,00	0,00	-	-	-	0,00	0,00	0,00	126,16
Zone 6	0,00	0,00	0,00	21	25	0,00	0,00	-	-	-	0,00	0,00	0,00	180,48

Table2. Input values for the different zones in the reference model.

Appendix B: Variations of occupant load and schedules $(C_A/C_D$ -values) in IDA ICE simulations

Occupant loads and schedules used for the reference model and related study cases are presented in this annex. Numbers of people passing the different entrances for each hour of the day are presented in Table 1. The variations are based on the estimation shown in Figure 2.7. Table 2-15 presents the resulting CA/CD values which correspond to entrance schedules used in IDA ICE. The schedules are calculated according to presented equations in Chapter 2.3.1.

Table 1. Occupant load for each entrance in the reference model

Travellers	11000
Occupants	15671

		PASSING PEOPLE											
			Entra		G	oto							
		Stud	died	Otl	her	U.	ue						
		Weekdays	Weekends	Weekdays	Weekends	Weekdays	Weekends						
00:00-00:59	0%	21	10	4	2	2	1						
01:00-01:59	0%	0	0	0	0	0	0						
02:00-02:59	0%	0	0	0	0	0	0						
03:00-03:59	0%	0	0	0	0	0	0						
04:00-04:59	0%	13	7	2	1	1	0						
05:00-05:59	1%	132	66	18	9	8	4						
06:00-06:59	4%	412	206	55	28	25	12						
07:00-07:59	11%	1073	537	144	72	64	32						
08:00-08:59	8%	822	411	111	55	49	25						
09:00-09:59	5%	540	270	73	36	32	16						
10:00-10:59	4%	418	209	56	28	25	13						
11:00-11:59	5%	508	254	68	34	31	15						
12:00-12:59	6%	574	287	77	39	34	17						
13:00-13:59	6%	579	290	78	39	35	17						
14:00-14:59	8%	813	406	109	55	49	24						
15:00-15:59	10%	1003	502	135	68	60	30						
16:00-16:59	10%	1022	511	138	69	61	31						
17:00-17:59	7%	763	381	103	51	46	23						
18:00-18:59	5%	499	250	67	34	30	15						
19:00-19:59	3%	320	160	43	22	19	10						
20:00-20:59	2%	249	125	34	17	15	7						
21:00-21:59	2%	211	105	28	14	13	6						
22:00-22:59	1%	122	61	16	8	7	4						
23:00-23:59	1%	73	36	10	5	4	2						
People per	dav	10186	5093	1371	686	11000	5500						

					REF	ERENCE	E SET	TINGS	-			
Time		G	ate			Entra	ances			Studied	entran	ice
Time	Wee	ekdays	Wee	ekends	We	ekdays	Wee	ekends	Wee	ekdays	Wee	ekends
	C _A	C_A/C_D	C _A	CA/C _D	C _A	CA/C_D	C _A	CA/C_D	C _A	C_A/C_D	C _A	C_A / C_D
00:00-00:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,02	0,01	0,01
01:00-01:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
02:00-02:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
03:00-03:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
04:00-04:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,00	0,00
05:00-05:59	0,01	0,01	0,00	0,00	0,01	0,02	0,00	0,01	0,10	0,15	0,05	0,07
06:00-06:59	0,03	0,02	0,01	0,01	0,04	0,06	0,02	0,03	0,26	0,40	0,15	0,22
07:00-07:59	0,07	0,05	0,03	0,03	0,10	0,16	0,05	0,08	0,62	0,95	0,32	0,48
08:00-08:59	0,05	0,04	0,03	0,02	0,08	0,12	0,04	0,06	0,53	0,82	0,26	0,40
09:00-09:59	0,03	0,03	0,02	0,01	0,05	0,08	0,03	0,04	0,32	0,49	0,18	0,28
10:00-10:59	0,03	0,02	0,01	0,01	0,04	0,06	0,02	0,03	0,26	0,40	0,15	0,23
11:00-11:59	0,03	0,02	0,02	0,01	0,05	0,08	0,02	0,04	0,30	0,46	0,18	0,27
12:00-12:59	0,04	0,03	0,02	0,01	0,06	0,09	0,03	0,04	0,34	0,52	0,19	0,30
13:00-13:59	0,04	0,03	0,02	0,01	0,06	0,09	0,03	0,04	0,34	0,52	0,20	0,30
14:00-14:59	0,05	0,04	0,03	0,02	0,08	0,12	0,04	0,06	0,53	0,81	0,26	0,39
15:00-15:59	0,06	0,05	0,03	0,02	0,10	0,15	0,05	0,08	0,62	0,95	0,30	0,45
16:00-16:59	0,06	0,05	0,03	0,02	0,10	0,15	0,05	0,08	0,62	0,95	0,30	0,46
17:00-17:59	0,05	0,04	0,02	0,02	0,08	0,12	0,04	0,06	0,48	0,74	0,24	0,38
18:00-18:59	0,03	0,02	0,02	0,01	0,05	0,08	0,02	0,04	0,29	0,45	0,17	0,27
19:00-19:59	0,02	0,02	0,01	0,01	0,03	0,05	0,01	0,02	0,21	0,33	0,12	0,18
20:00-20:59	0,02	0,01	0,01	0,01	0,02	0,04	0,01	0,02	0,17	0,26	0,09	0,14
21:00-21:59	0,01	0,01	0,01	0,00	0,02	0,03	0,01	0,01	0,15	0,23	0,08	0,12
22:00-22:59	0,01	0,01	0,00	0,00	0,01	0,02	0,00	0,01	0,09	0,14	0,04	0,07
23:00-23:59	0,00	0,00	0,00	0,00	0,01	0,01	0,00	0,00	0,05	0,08	0,03	0,04

Table 2. Calculated C_A and C_A/C_D values for the entrances in the reference model. Notice that $C_D=0.65[m^3/m^2,S,P_a^n]$.

	STUDY OF SOUTH-WEST ENTRANCE																			
Timo	Slid	ingdoor	90° ve	stibule	Swi	inging do	or ves	stibule	Swin	ging door	r 90° v	estibule	Sir	ngle Swi	nging	Door	Si	ingle Sli	ding D	oor
TIME	Wee	ekdays	Wee	ekends	We	ekdays	We	ekends	We	ekdays	Wee	ekends	Wee	ekdays	Wee	ekends	Wee	ekdays	Wee	ekends
	C _A	C_A/C_D	C _A	C_A/C_D	C _A	C_A/C_D	C _A	C_A/C_D	C _A	C_A / C_D	C _A	C_A / C_D	C _A	C_A / C_D	C _A	C_A/C_D	C _A	C_A/C_D	C _A	C _A /C _D
00:00-00:59	0,01	0,02	0,01	0,01	0,02	0,02	0,01	0,01	0,01	0,01	0,00	0,01	0,03	0,04	0,01	0,02	0,02	0,03	0,01	0,02
01:00-01:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
02:00-02:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
03:00-03:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
04:00-04:59	0,01	0,01	0,00	0,00	0,01	0,01	0,00	0,00	0,00	0,01	0,00	0,00	0,02	0,02	0,01	0,01	0,01	0,02	0,01	0,01
05:00-05:59	0,08	0,13	0,04	0,07	0,11	0,17	0,05	0,08	0,06	0,09	0,03	0,05	0,15	0,24	0,08	0,12	0,13	0,20	0,07	0,11
06:00-06:59	0,22	0,34	0,13	0,19	0,28	0,44	0,16	0,25	0,15	0,24	0,09	0,14	0,38	0,59	0,23	0,35	0,33	0,51	0,20	0,30
07:00-07:59	0,35	0,54	0,27	0,42	0,62	0,95	0,33	0,50	0,35	0,54	0,20	0,31	0,62	0,95	0,47	0,72	0,62	0,95	0,40	0,62
08:00-08:59	0,34	0,52	0,22	0,34	0,53	0,81	0,28	0,43	0,31	0,48	0,15	0,24	0,60	0,92	0,39	0,60	0,56	0,87	0,33	0,51
09:00-09:59	0,27	0,42	0,16	0,24	0,33	0,50	0,20	0,31	0,21	0,32	0,11	0,17	0,47	0,72	0,27	0,41	0,40	0,62	0,24	0,38
10:00-10:59	0,22	0,34	0,13	0,19	0,29	0,44	0,16	0,25	0,15	0,24	0,09	0,14	0,38	0,59	0,23	0,36	0,34	0,52	0,20	0,30
11:00-11:59	0,26	0,40	0,15	0,23	0,31	0,48	0,19	0,30	0,20	0,30	0,11	0,16	0,45	0,70	0,25	0,38	0,39	0,60	0,23	0,36
12:00-12:59	0,28	0,43	0,17	0,26	0,35	0,53	0,21	0,33	0,22	0,33	0,12	0,18	0,49	0,75	0,28	0,44	0,42	0,65	0,26	0,40
13:00-13:59	0,28	0,43	0,17	0,26	0,35	0,54	0,22	0,33	0,22	0,33	0,12	0,18	0,49	0,76	0,29	0,44	0,42	0,65	0,26	0,40
14:00-14:59	0,33	0,51	0,22	0,33	0,52	0,80	0,28	0,43	0,31	0,47	0,15	0,23	0,59	0,91	0,39	0,59	0,56	0,86	0,33	0,51
15:00-15:59	0,35	0,54	0,26	0,40	0,62	0,95	0,31	0,47	0,35	0,54	0,19	0,30	0,62	0,95	0,45	0,69	0,62	0,95	0,39	0,60
16:00-16:59	0,35	0,54	0,26	0,40	0,62	0,95	0,31	0,48	0,35	0,54	0,20	0,30	0,62	0,95	0,45	0,70	0,62	0,95	0,39	0,60
17:00-17:59	0,32	0,50	0,21	0,32	0,48	0,74	0,27	0,41	0,28	0,44	0,15	0,22	0,57	0,88	0,37	0,57	0,53	0,81	0,32	0,49
18:00-18:59	0,26	0,40	0,15	0,23	0,31	0,47	0,19	0,29	0,19	0,30	0,10	0,16	0,45	0,69	0,24	0,37	0,39	0,59	0,23	0,35
19:00-19:59	0,18	0,28	0,10	0,15	0,23	0,36	0,13	0,20	0,13	0,20	0,07	0,11	0,32	0,50	0,18	0,28	0,28	0,43	0,16	0,24
20:00-20:59	0,15	0,23	0,08	0,12	0,19	0,29	0,10	0,16	0,10	0,16	0,06	0,09	0,27	0,41	0,15	0,23	0,23	0,35	0,12	0,19
21:00-21:59	0,13	0,20	0,07	0,10	0,16	0,25	0,09	0,13	0,09	0,14	0,05	0,07	0,23	0,36	0,13	0,19	0,20	0,31	0,11	0,16
22:00-22:59	0,08	0,12	0,04	0,06	0,10	0,15	0,05	0,08	0,05	0,08	0,03	0,04	0,14	0,22	0,07	0,11	0,12	0,19	0,06	0,10
23:00-23:59	0,05	0,07	0,02	0,04	0,06	0,09	0,03	0,05	0,03	0,05	0,02	0,02	0,09	0,14	0,04	0,07	0,08	0,12	0,04	0,06

Table 3. Calculated C_A and C_A/C_D values for the entrances in the south-west entrance study. Notice that $C_D=0.65[m^3/m^2,S,P_a^n]$.

									STUD	Y OF GA	ATE O	PENING								
Timo	Slid	ingdoor	90° ve	stibule	Swi	inging do	oor ve	stibule	Swin	ging door	: 90° v	vestibule	Sli	ding doo	or vest	ibule	Swi	nging do	or ves	stibule
Time	Wee	ekdays	Wee	ekends	Wee	ekdays	Wee	ekends	We	ekdays	Wee	ekends	Wee	ekdays	Wee	ekends	Wee	ekdays	Wee	ekends
	C _A	C_A/C_D	C _A	C_A / C_D	C _A	C_A/C_D	C _A	C_A/C_D	C _A	C_A / C_D										
00:00-00:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
01:00-01:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
02:00-02:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
03:00-03:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
04:00-04:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
05:00-05:59	0,00	0,01	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,01	0,00	0,00
06:00-06:59	0,01	0,02	0,01	0,01	0,02	0,03	0,01	0,01	0,01	0,02	0,00	0,01	0,02	0,03	0,01	0,01	0,02	0,03	0,01	0,01
07:00-07:59	0,04	0,06	0,02	0,03	0,05	0,08	0,03	0,04	0,03	0,04	0,01	0,02	0,05	0,07	0,02	0,04	0,05	0,08	0,03	0,04
08:00-08:59	0,03	0,05	0,01	0,02	0,04	0,06	0,02	0,03	0,02	0,03	0,01	0,02	0,04	0,06	0,02	0,03	0,04	0,06	0,02	0,03
09:00-09:59	0,02	0,03	0,01	0,01	0,03	0,04	0,01	0,02	0,01	0,02	0,01	0,01	0,02	0,04	0,01	0,02	0,03	0,04	0,01	0,02
10:00-10:59	0,02	0,02	0,01	0,01	0,02	0,03	0,01	0,01	0,01	0,02	0,00	0,01	0,02	0,03	0,01	0,01	0,02	0,03	0,01	0,01
11:00-11:59	0,02	0,03	0,01	0,01	0,02	0,04	0,01	0,02	0,01	0,02	0,01	0,01	0,02	0,03	0,01	0,01	0,02	0,04	0,01	0,02
12:00-12:59	0,02	0,03	0,01	0,02	0,03	0,04	0,01	0,02	0,01	0,02	0,01	0,01	0,02	0,04	0,01	0,02	0,03	0,04	0,01	0,02
13:00-13:59	0,02	0,03	0,01	0,02	0,03	0,04	0,01	0,02	0,02	0,02	0,01	0,01	0,02	0,04	0,01	0,02	0,03	0,04	0,01	0,02
14:00-14:59	0,03	0,05	0,01	0,02	0,04	0,06	0,02	0,03	0,02	0,03	0,01	0,02	0,04	0,05	0,02	0,03	0,04	0,06	0,02	0,03
15:00-15:59	0,04	0,06	0,02	0,03	0,05	0,08	0,02	0,04	0,03	0,04	0,01	0,02	0,04	0,07	0,02	0,03	0,05	0,08	0,02	0,04
16:00-16:59	0,04	0,06	0,02	0,03	0,05	0,08	0,02	0,04	0,03	0,04	0,01	0,02	0,05	0,07	0,02	0,03	0,05	0,08	0,02	0,04
17:00-17:59	0,03	0,04	0,01	0,02	0,04	0,06	0,02	0,03	0,02	0,03	0,01	0,01	0,03	0,05	0,02	0,02	0,04	0,06	0,02	0,03
18:00-18:59	0,02	0,03	0,01	0,01	0,02	0,04	0,01	0,02	0,01	0,02	0,01	0,01	0,02	0,03	0,01	0,01	0,02	0,04	0,01	0,02
19:00-19:59	0,01	0,02	0,00	0,01	0,01	0,02	0,01	0,01	0,01	0,01	0,00	0,00	0,01	0,02	0,01	0,01	0,01	0,02	0,01	0,01
20:00-20:59	0,01	0,01	0,00	0,00	0,01	0,02	0,00	0,01	0,01	0,01	0,00	0,00	0,01	0,01	0,00	0,01	0,01	0,02	0,00	0,01
21:00-21:59	0,01	0,01	0,00	0,00	0,01	0,01	0,00	0,00	0,00	0,01	0,00	0,00	0,01	0,01	0,00	0,00	0,01	0,01	0,00	0,00
22:00-22:59	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,01	0,00	0,00
23:00-23:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Table 4. Calculated C_A and C_A/C_D values for the entrances in the gate opening study. Notice that $C_D=0.65[m^3/m^2,S,P_a^n]$.

	STUDY OF GATE OPENING						
Timo	Si	ngle Swi	nging I	Door			
TIME	Wee	ekdays	Wee	ekends			
	C _A	C_A/C_D	C _A	C_A/C_D			
00:00-00:59	0,00	0,00	0,00	0,00			
01:00-01:59	0,00	0,00	0,00	0,00			
02:00-02:59	0,00	0,00	0,00	0,00			
03:00-03:59	0,00	0,00	0,00	0,00			
04:00-04:59	0,00	0,00	0,00	0,00			
05:00-05:59	0,01	0,01	0,00	0,01			
06:00-06:59	0,03	0,05	0,01	0,02			
07:00-07:59	0,08	0,12	0,04	0,06			
08:00-08:59	0,06	0,09	0,03	0,05			
09:00-09:59	0,04	0,06	0,02	0,03			
10:00-10:59	0,03	0,05	0,01	0,02			
11:00-11:59	0,04	0,06	0,02	0,03			
12:00-12:59	0,04	0,06	0,02	0,03			
13:00-13:59	0,04	0,07	0,02	0,03			
14:00-14:59	0,06	0,09	0,03	0,05			
15:00-15:59	0,07	0,11	0,04	0,06			
16:00-16:59	0,07	0,11	0,04	0,06			
17:00-17:59	0,06	0,09	0,03	0,04			
18:00-18:59	0,04	0,06	0,02	0,03			
19:00-19:59	0,02	0,04	0,01	0,02			
20:00-20:59	0,02	0,03	0,01	0,01			
21:00-21:59	0,01	0,02	0,01	0,01			
22:00-22:59	0,01	0,01	0,00	0,00			
23:00-23:59	0,00	0,01	0,00	0,00			

Table 5. Calculated C_A and C_A/C_D values for the entrances in the gate opening study. Notice that $C_D=0.65[m^3/m^2, S, P_a^n]$.

-	Ū	PASSING PEOPLE 11 000 TRAVELERS											
			Entra	ances		C			Occupa	nt loa	d		
		Stud	died	Ot	her	G	ate	occupants	n	%	n	%	
		Weekdays	Weekends	Weekdays	Weekends	Weekdays	Weekends	wee	ekdays		week	ends	
00:00-00:59	0%	20,77	10,39	3,98	1,99	1,78	0,89	45,53	5,31	0,03	2,66	0,01	
01:00-01:59	0%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
02:00-02:59	0%	0,00	0,00	0,08	0,04	0,04	0,02	0,00	0,00	0,00	0,00	0,00	
03:00-03:59	0%	0,00	0,00	0,07	0,03	0,03	0,02	0,00	0,00	0,00	0,00	0,00	
04:00-04:59	0%	13,10	6,55	1,76	0,88	0,79	0,39	20,15	2,35	0,01	1,18	0,01	
05:00-05:59	1%	132,05	66,02	17,78	8,89	7,92	3,96	203,15	23,71	0,12	11,85	0,06	
06:00-06:59	4%	412,28	206,14	55,50	27,75	24,73	12,37	634,28	74,02	0,38	37,01	0,19	
07:00-07:59	11%	1073,19	536,60	144,47	72,23	64,39	32,19	1651,07	192,68	1,00	96,34	0,50	
08:00-08:59	8%	821,70	410,85	110,61	55,31	49,30	24,65	1264,15	147,53	0,77	73,76	0,38	
09:00-09:59	5%	539,94	269,97	72,68	36,34	32,39	16,20	830,68	96,94	0,50	48,47	0,25	
10:00-10:59	4%	417,96	208,98	56,26	28,13	25,08	12,54	643,01	75,04	0,39	37,52	0,19	
11:00-11:59	5%	508,41	254,21	68,44	34,22	30,50	15,25	782,17	91,28	0,47	45,64	0,24	
12:00-12:59	6%	574,26	287,13	77,30	38,65	34,45	17,23	883,48	103,10	0,54	51,55	0,27	
13:00-13:59	6%	579,23	289,62	77,97	38,99	34,75	17,38	891,12	103,99	0,54	52,00	0,27	
14:00-14:59	8%	812,86	406,43	109,42	54,71	48,77	24,38	1250,55	145,94	0,76	72,97	0,38	
15:00-15:59	10%	1003,08	501,54	135,03	67,51	60,18	30,09	1543,19	180,09	0,93	90,05	0,47	
16:00-16:59	10%	1022,25	511,12	137,61	68,80	61,33	30,66	1572,68	183,53	0,95	91,77	0,48	
17:00-17:59	7%	762,64	381,32	102,66	51,33	45,75	22,88	1173,30	136,92	0,71	68,46	0,36	
18:00-18:59	5%	499,07	249,53	67,18	33,59	29,94	14,97	767,80	89,60	0,47	44,80	0,23	
19:00-19:59	3%	319,93	159,96	43,07	21,53	19,19	9,60	492,20	57,44	0,30	28,72	0,15	
20:00-20:59	2%	249,08	124,54	33,53	16,76	14,94	7,47	383,19	44,72	0,23	22,36	0,12	
21:00-21:59	2%	210,52	105,26	28,34	14,17	12,63	6,32	323,88	37,80	0,20	18,90	0,10	
22:00-22:59	1%	121,97	60,98	16,42	8,21	7,32	3,66	187,64	21,90	0,11	10,95	0,06	
23:00-23:59	1%	72,82	36,41	9,80	4,90	4,37	2,18	112,03	13,07	0,07	6,54	0,03	
People per	day	10186,15	5093,08	1371,21	685,61	11000,00	5500,00	15655,27	192,68				

Table 6. Occupant load for each entrance when 11 000 traveler uses NET.

	SETTINGS 11 000 TRAVELERS											
Time		Entra	ances			Studied	entran	ice				
Time	Wee	ekdays	Wee	ekends	Wee	ekdays	Wee	ekends	Wee	ekdays	Wee	ekends
	C _A	C_A/C_D	C _A	C_A / C_D	CA	C_A / C_D	C _A	C_A / C_D	C _A	C_A / C_D	C _A	C_A / C_D
00:00-00:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,02	0,01	0,01
01:00-01:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
02:00-02:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
03:00-03:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
04:00-04:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,00	0,00
05:00-05:59	0,01	0,01	0,00	0,00	0,01	0,02	0,00	0,01	0,10	0,15	0,05	0,07
06:00-06:59	0,03	0,04	0,01	0,02	0,04	0,06	0,02	0,03	0,26	0,40	0,15	0,22
07:00-07:59	0,07	0,10	0,03	0,05	0,10	0,16	0,05	0,08	0,62	0,95	0,32	0,48
08:00-08:59	0,05	0,08	0,03	0,04	0,08	0,12	0,04	0,06	0,53	0,82	0,26	0,40
09:00-09:59	0,03	0,05	0,02	0,03	0,05	0,08	0,03	0,04	0,32	0,49	0,18	0,28
10:00-10:59	0,03	0,04	0,01	0,02	0,04	0,06	0,02	0,03	0,26	0,40	0,15	0,23
11:00-11:59	0,03	0,05	0,02	0,02	0,05	0,08	0,02	0,04	0,30	0,46	0,18	0,27
12:00-12:59	0,04	0,06	0,02	0,03	0,06	0,09	0,03	0,04	0,34	0,52	0,19	0,30
13:00-13:59	0,04	0,06	0,02	0,03	0,06	0,09	0,03	0,04	0,34	0,52	0,20	0,30
14:00-14:59	0,05	0,08	0,03	0,04	0,08	0,12	0,04	0,06	0,53	0,81	0,26	0,39
15:00-15:59	0,06	0,10	0,03	0,05	0,10	0,15	0,05	0,08	0,62	0,95	0,30	0,45
16:00-16:59	0,06	0,10	0,03	0,05	0,10	0,15	0,05	0,08	0,62	0,95	0,30	0,46
17:00-17:59	0,05	0,07	0,02	0,04	0,08	0,12	0,04	0,06	0,48	0,74	0,24	0,38
18:00-18:59	0,03	0,05	0,02	0,02	0,05	0,08	0,02	0,04	0,29	0,45	0,17	0,27
19:00-19:59	0,02	0,03	0,01	0,01	0,03	0,05	0,01	0,02	0,21	0,33	0,12	0,18
20:00-20:59	0,02	0,02	0,01	0,01	0,02	0,04	0,01	0,02	0,17	0,26	0,09	0,14
21:00-21:59	0,01	0,02	0,01	0,01	0,02	0,03	0,01	0,01	0,15	0,23	0,08	0,12
22:00-22:59	0,01	0,01	0,00	0,00	0,01	0,02	0,00	0,01	0,09	0,14	0,04	0,07
23:00-23:59	0,00	0,01	0,00	0,00	0,01	0,01	0,00	0,00	0,05	0,08	0,03	0,04

Table 7. Calculated C_A and C_A/C_D values when 11 000 traveler uses NET. Notice that $C_D=0.65[m^3/m^2,S,P_a^n]$.

			PASSING PEOPLE 15 000 TRAVELERS												
			Entra	ances		C	ata		Occupa	ant loa	ıd				
		Stud	died	Ot	her	Ga	ale	occupants	n	%	n	%			
		Weekdays	Weekends	Weekdays	Weekends	Weekdays	Weekends	wee	ekdays		weeke	ends			
00:00-00:59	0%	37,15	18,57	5,00	2,50	2,42	1,21	57,15	6,67	0,03	3,33	0,01			
01:00-01:59	0%	11,41	5,71	1,54	0,77	0,74	0,37	17,56	2,05	0,01	1,02	0,00			
02:00-02:59	0%	0,77	0,39	0,10	0,05	0,05	0,03	1,19	0,14	0,00	0,07	0,00			
03:00-03:59	0%	0,65	0,32	0,09	0,04	0,04	0,02	1,00	0,12	0,00	0,06	0,00			
04:00-04:59	0%	16,44	8,22	2,21	1,11	1,07	0,54	25,29	2,95	0,01	1,48	0,01			
05:00-05:59	1%	165,75	82,87	22,31	11,16	10,80	5,40	255,00	29,76	0,12	14,88	0,06			
06:00-06:59	4%	517,52	258,76	69,67	34,83	33,73	16,86	796,18	92,91	0,38	46,46	0,19			
07:00-07:59	11%	1347,13	673,56	181,34	90,67	87,80	43,90	2072,50	241,86	1,00	120,93	0,50			
08:00-08:59	8%	1031,44	515,72	138,85	69,42	67,22	33,61	1586,83	185,18	0,77	92,59	0,38			
09:00-09:59	5%	677,76	338,88	91,24	45,62	44,17	22,09	1042,71	121,68	0,50	60,84	0,25			
10:00-10:59	4%	524,64	262,32	70,62	35,31	34,19	17,10	807,14	94,19	0,39	47,10	0,19			
11:00-11:59	5%	638,18	319,09	85,91	42,95	41,59	20,80	981,82	114,58	0,47	57,29	0,24			
12:00-12:59	6%	720,84	360,42	97,04	48,52	46,98	23,49	1108,98	129,42	0,54	64,71	0,27			
13:00-13:59	6%	727,08	363,54	97,88	48,94	47,39	23,69	1118,58	130,54	0,54	65,27	0,27			
14:00-14:59	8%	1020,34	510,17	137,35	68,68	66,50	33,25	1569,75	183,19	0,76	91,60	0,38			
15:00-15:59	10%	1259,11	629,56	169,50	84,75	82,06	41,03	1937,09	226,06	0,93	113,03	0,47			
16:00-16:59	10%	1283,17	641,59	172,73	86,37	83,63	41,82	1974,11	230,38	0,95	115,19	0,48			
17:00-17:59	7%	957,31	478,65	128,87	64,43	62,39	31,20	1472,78	171,87	0,71	85,94	0,36			
18:00-18:59	5%	626,46	313,23	84,33	42,17	40,83	20,41	963,78	112,47	0,47	56,24	0,23			
19:00-19:59	3%	401,59	200,79	54,06	27,03	26,17	13,09	617,83	72,10	0,30	36,05	0,15			
20:00-20:59	2%	312,65	156,33	42,09	21,04	20,38	10,19	481,00	56,13	0,23	28,07	0,12			
21:00-21:59	2%	264,26	132,13	35,57	17,79	17,22	8,61	406,55	47,44	0,20	23,72	0,10			
22:00-22:59	1%	153,10	76,55	20,61	10,30	9,98	4,99	235,54	27,49	0,11	13,74	0,06			
23:00-23:59	1%	91,41	45,70	12,30	6,15	5,96	2,98	140,63	16,41	0,07	8,21	0,03			
People per	day	12786,15	6393,08	1721,21	860,61	15000,00	7500,00	19671,00	241,86						

Table 8. Occupant load for each entrance when 15 000 traveler uses NET.

					Settings 15 000 travelers								
Timo		Ga	ate			Entra	ances			Studied	entran	ice	
TIME	Wee	ekdays	Wee	ekends	Wee	ekdays	Wee	ekends	Wee	ekdays	Wee	ekends	
	C_A	C_A/C_D	C_A	C_A / C_D	C_A	C_A / C_D	CA	C_A / C_D	C_A	C_A / C_D	C_A	C_A / C_D	
00:00-00:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,04	0,01	0,02	
01:00-01:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,00	0,00	
02:00-02:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
03:00-03:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
04:00-04:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,02	0,00	0,01	
05:00-05:59	0,01	0,01	0,00	0,00	0,02	0,02	0,01	0,01	0,12	0,18	0,06	0,09	
06:00-06:59	0,04	0,03	0,02	0,01	0,05	0,08	0,02	0,04	0,30	0,47	0,18	0,27	
07:00-07:59	0,09	0,07	0,05	0,04	0,13	0,20	0,07	0,10	0,62	0,95	0,41	0,62	
08:00-08:59	0,07	0,05	0,03	0,03	0,10	0,16	0,05	0,08	0,62	0,95	0,30	0,47	
09:00-09:59	0,05	0,04	0,02	0,02	0,07	0,10	0,03	0,05	0,41	0,63	0,22	0,34	
10:00-10:59	0,04	0,03	0,02	0,01	0,05	0,08	0,03	0,04	0,31	0,47	0,18	0,28	
11:00-11:59	0,04	0,03	0,02	0,02	0,06	0,10	0,03	0,05	0,38	0,59	0,21	0,33	
12:00-12:59	0,05	0,04	0,02	0,02	0,07	0,11	0,04	0,05	0,44	0,68	0,23	0,36	
13:00-13:59	0,05	0,04	0,02	0,02	0,07	0,11	0,04	0,06	0,45	0,69	0,24	0,36	
14:00-14:59	0,07	0,05	0,03	0,03	0,10	0,15	0,05	0,08	0,62	0,95	0,30	0,46	
15:00-15:59	0,08	0,06	0,04	0,03	0,12	0,19	0,06	0,10	0,62	0,95	0,37	0,58	
16:00-16:59	0,09	0,07	0,04	0,03	0,12	0,19	0,06	0,10	0,62	0,95	0,38	0,59	
17:00-17:59	0,06	0,05	0,03	0,02	0,09	0,14	0,05	0,07	0,62	0,95	0,28	0,44	
18:00-18:59	0,04	0,03	0,02	0,02	0,06	0,10	0,03	0,05	0,37	0,57	0,21	0,32	
19:00-19:59	0,03	0,02	0,01	0,01	0,04	0,06	0,02	0,03	0,25	0,39	0,14	0,22	
20:00-20:59	0,02	0,02	0,01	0,01	0,03	0,05	0,01	0,02	0,21	0,32	0,11	0,17	
21:00-21:59	0,02	0,01	0,01	0,01	0,03	0,04	0,01	0,02	0,18	0,28	0,10	0,15	
22:00-22:59	0,01	0,01	0,00	0,00	0,01	0,02	0,01	0,01	0,11	0,17	0,06	0,09	
23:00-23:59	0,01	0,00	0,00	0,00	0,01	0,01	0,00	0,00	0,07	0,10	0,03	0,05	

Table 9. Calculated C_A and C_A/C_D values when 15 000 traveler uses NET. Notice that $C_D=0.65[m^3/m^2,S,P_a^n]$.

			PASSING PEOPLE 20 000 TRAVELERS												
			Entra	ances		C	ata		Occupa	ant loa	ıd				
		Studied		Other		U.	ale	occupants	n	%	n	%			
		Weekdays Weekend		Weekdays Weekends		Weekdays	Weekends	weekdays			weekends				
00:00-00:59	0%	46,59	23,30	6,27	3,14	3,23	1,61	71,68	8,37	0,03	4,18	0,01			
01:00-01:59	0%	14,31	7,16	1,93	0,96	0,99	0,50	22,02	2,57	0,01	1,28	0,00			
02:00-02:59	0%	0,97	0,49	0,13	0,07	0,07	0,03	1,50	0,17	0,00	0,09	0,00			
03:00-03:59	0%	0,81	0,41	0,11	0,05	0,06	0,03	1,25	0,15	0,00	0,07	0,00			
04:00-04:59	0%	20,62	10,31	2,78	1,39	1,43	0,71	31,72	3,70	0,01	1,85	0,01			
05:00-05:59	1%	207,88	103,94	27,98	13,99	14,40	7,20	319,82	37,32	0,12	18,66	0,06			
06:00-06:59	4%	649,06	324,53	87,37	43,69	44,97	22,49	998,56	116,53	0,38	58,27	0,19			
07:00-07:59	11%	1689,54	844,77	227,44	113,72	117,06	58,53	2599,29	303,34	1,00	151,67	0,50			
08:00-08:59	8%	1293,61	646,80	174,14	87,07	89,63	44,82	1990,17	232,25	0,77	116,13	0,38			
09:00-09:59	5%	850,04	425,02	114,43	57,21	58,90	29,45	1307,75	152,61	0,50	76,31	0,25			
10:00-10:59	4%	657,99	329,00	88,58	44,29	45,59	22,80	1012,30	118,14	0,39	59,07	0,19			
11:00-11:59	5%	800,40	400,20	107,75	53,87	55,46	27,73	1231,38	143,70	0,47	71,85	0,24			
12:00-12:59	6%	904,06	452,03	121,70	60,85	62,64	31,32	1390,86	162,31	0,54	81,16	0,27			
13:00-13:59	6%	911,89	455,94	122,75	61,38	63,18	31,59	1402,90	163,72	0,54	81,86	0,27			
14:00-14:59	8%	1279,69	639,84	172,27	86,13	88,67	44,33	1968,75	229,75	0,76	114,88	0,38			
15:00-15:59	10%	1579,15	789,58	212,58	106,29	109,42	54,71	2429,47	283,52	0,93	141,76	0,47			
16:00-16:59	10%	1609,33	804,67	216,64	108,32	111,51	55,75	2475,89	288,94	0,95	144,47	0,48			
17:00-17:59	7%	1200,64	600,32	161,62	80,81	83,19	41,59	1847,13	215,56	0,71	107,78	0,36			
18:00-18:59	5%	785,69	392,84	105,77	52,88	54,44	27,22	1208,75	141,06	0,47	70,53	0,23			
19:00-19:59	3%	503,67	251,83	67,80	33,90	34,90	17,45	774,87	90,43	0,30	45,21	0,15			
20:00-20:59	2%	392,12	196,06	52,79	26,39	27,17	13,58	603,27	70,40	0,23	35,20	0,12			
21:00-21:59	2%	331,43	165,71	44,62	22,31	22,96	11,48	509,89	59,50	0,20	29,75	0,10			
22:00-22:59	1%	192,02	96,01	25,85	12,92	13,30	6,65	295,41	34,47	0,11	17,24	0,06			
23:00-23:59	1%	114,64	57,32	15,43	7,72	7,94	3,97	176,37	20,58	0,07	10,29	0,03			
People per day		16036,15	8018,08	2158,71	1079,36	20000,00	10000,00	24671,00	303,34						

Table 10. Occupant load for each entrance when 20 000 traveler uses NET.

					Setti	ngs 20 (000 tra	avelers				
Time		Ga	ate			Entra	ances		Studied entrance			
Time	Weekdays		Weekends		Weekdays		Weekends		Wee	ekdays	Wee	ekends
	C_A	C_A/C_D	CA	C_A / C_D	C_A	C_A / C_D	CA	C_A / C_D	C_A	C_A / C_D	C_A	C_A / C_D
00:00-00:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,05	0,02	0,02
01:00-01:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,00	0,01
02:00-02:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
03:00-03:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
04:00-04:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,02	0,01	0,01
05:00-05:59	0,01	0,01	0,01	0,01	0,02	0,03	0,01	0,01	0,15	0,23	0,08	0,12
06:00-06:59	0,05	0,04	0,02	0,02	0,06	0,10	0,03	0,05	0,39	0,60	0,22	0,33
07:00-07:59	0,12	0,09	0,06	0,05	0,16	0,24	0,08	0,13	0,62	0,95	0,56	0,86
08:00-08:59	0,09	0,07	0,05	0,04	0,12	0,19	0,06	0,10	0,62	0,95	0,39	0,59
09:00-09:59	0,06	0,05	0,03	0,02	0,08	0,13	0,04	0,06	0,56	0,87	0,27	0,41
10:00-10:59	0,05	0,04	0,02	0,02	0,07	0,10	0,03	0,05	0,39	0,61	0,22	0,33
11:00-11:59	0,06	0,04	0,03	0,02	0,08	0,12	0,04	0,06	0,51	0,79	0,25	0,39
12:00-12:59	0,06	0,05	0,03	0,03	0,09	0,14	0,04	0,07	0,62	0,95	0,27	0,41
13:00-13:59	0,07	0,05	0,03	0,03	0,09	0,14	0,05	0,07	0,62	0,95	0,27	0,42
14:00-14:59	0,09	0,07	0,05	0,04	0,12	0,19	0,06	0,10	0,62	0,95	0,38	0,59
15:00-15:59	0,11	0,09	0,06	0,04	0,15	0,23	0,08	0,12	0,62	0,95	0,50	0,77
16:00-16:59	0,11	0,09	0,06	0,04	0,15	0,23	0,08	0,12	0,62	0,95	0,52	0,80
17:00-17:59	0,09	0,07	0,04	0,03	0,12	0,18	0,06	0,09	0,62	0,95	0,35	0,55
18:00-18:59	0,06	0,04	0,03	0,02	0,08	0,12	0,04	0,06	0,50	0,77	0,25	0,38
19:00-19:59	0,04	0,03	0,02	0,01	0,05	0,08	0,02	0,04	0,30	0,46	0,17	0,27
20:00-20:59	0,03	0,02	0,01	0,01	0,04	0,06	0,02	0,03	0,25	0,38	0,14	0,21
21:00-21:59	0,02	0,02	0,01	0,01	0,03	0,05	0,02	0,02	0,22	0,34	0,12	0,18
22:00-22:59	0,01	0,01	0,01	0,00	0,02	0,03	0,01	0,01	0,14	0,21	0,07	0,11
23:00-23:59	0,01	0,01	0,00	0,00	0,01	0,02	0,00	0,01	0,08	0,13	0,04	0,06

Table 11. Calculated C_A and C_A/C_D values when 20 000 traveler uses NET. Notice that $C_D=0.65[m^3/m^2,S,P_a^n]$.

			PASSING PEOPLE 30 000 TRAVELERS											
			Entra	ances		C			Occupa	ant loa	ıd			
		Studied		Other		U.	ale	occupants	n	%	n	%		
		Weekdays Weekends		Weekdays Weekends		Weekdays	Weekends	weekdays			weekends			
00:00-00:59	0%	65,48	32,74	8,81	4,41	4,84	2,42	100,74	11,76	0,03	5,88	0,01		
01:00-01:59	0%	20,12	10,06	2,71	1,35	1,49	0,74	30,95	3,61	0,01	1,81	0,00		
02:00-02:59	0%	1,37	0,68	0,18	0,09	0,10	0,05	2,10	0,25	0,00	0,12	0,00		
03:00-03:59	0%	1,14	0,57	0,15	0,08	0,08	0,04	1,76	0,21	0,00	0,10	0,00		
04:00-04:59	0%	28,97	14,49	3,90	1,95	2,14	1,07	44,58	5,20	0,01	2,60	0,01		
05:00-05:59	1%	292,14	146,07	39,33	19,66	21,61	10,80	449,45	52,45	0,12	26,23	0,06		
06:00-06:59	4%	912,15	456,08	122,79	61,39	67,46	33,73	1403,31	163,77	0,38	81,88	0,19		
07:00-07:59	11%	2374,37	1187,18	319,63	159,81	175,60	87,80	3652,88	426,29	1,00	213,15	0,50		
08:00-08:59	8%	1817,95	908,98	244,72	122,36	134,45	67,22	2796,85	326,39	0,77	163,20	0,38		
09:00-09:59	5%	1194,58	597,29	160,81	80,40	88,35	44,17	1837,82	214,47	0,50	107,24	0,25		
10:00-10:59	4%	924,70	462,35	124,48	62,24	68,39	34,19	1422,62	166,02	0,39	83,01	0,19		
11:00-11:59	5%	1124,83	562,41	151,42	75,71	83,19	41,59	1730,50	201,95	0,47	100,97	0,24		
12:00-12:59	6%	1270,51	635,25	171,03	85,51	93,96	46,98	1954,63	228,11	0,54	114,05	0,27		
13:00-13:59	6%	1281,51	640,75	172,51	86,26	94,77	47,39	1971,55	230,08	0,54	115,04	0,27		
14:00-14:59	8%	1798,39	899,20	242,09	121,05	133,00	66,50	2766,76	322,88	0,76	161,44	0,38		
15:00-15:59	10%	2219,24	1109,62	298,74	149,37	164,12	82,06	3414,21	398,44	0,93	199,22	0,47		
16:00-16:59	10%	2261,65	1130,82	304,45	152,23	167,26	83,63	3479,46	406,05	0,95	203,03	0,48		
17:00-17:59	7%	1687,29	843,65	227,14	113,57	124,78	62,39	2595,84	302,93	0,71	151,47	0,36		
18:00-18:59	5%	1104,16	552,08	148,64	74,32	81,66	40,83	1698,70	198,24	0,47	99,12	0,23		
19:00-19:59	3%	707,82	353,91	95,28	47,64	52,35	26,17	1088,95	127,08	0,30	63,54	0,15		
20:00-20:59	2%	551,06	275,53	74,18	37,09	40,75	20,38	847,79	98,94	0,23	49,47	0,12		
21:00-21:59	2%	465,76	232,88	62,70	31,35	34,45	17,22	716,56	83,62	0,20	41,81	0,10		
22:00-22:59	1%	269,85	134,92	36,33	18,16	19,96	9,98	415,15	48,45	0,11	24,22	0,06		
23:00-23:59	1%	161,11	80,56	21,69	10,84	11,92	5,96	247,86	28,93	0,07	14,46	0,03		
People per	day	22536,15	11268,08	3033,71	1516,86	30000,00	15000,00	34671,00	426,29					

Table 12. Occupant load for each entrance when 30 000 traveler uses NET.

				SI	ETTIN	IGS 30 0	00 TR	AVELE	RS			
Time		Ga	ate			Entra	ances			Studied	entran	ice
Time	Weekdays		Weekends		Weekdays		Weekends		Weekdays		We	ekends
	CA	CA/CD	CA	CA/CD	CA	CA/CD	CA	CA/CD	CA	CA/CD	CA	CA/CD
00:00-00:59	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,05	0,07	0,02	0,04
01:00-01:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,02	0,01	0,01
02:00-02:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
03:00-03:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
04:00-04:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,03	0,01	0,01
05:00-05:59	0,02	0,02	0,01	0,01	0,03	0,04	0,01	0,02	0,20	0,30	0,11	0,16
06:00-06:59	0,07	0,05	0,04	0,03	0,09	0,14	0,05	0,07	0,62	0,95	0,27	0,42
07:00-07:59	0,17	0,13	0,09	0,07	0,21	0,33	0,12	0,18	0,62	0,95	0,62	0,95
08:00-08:59	0,13	0,10	0,07	0,05	0,17	0,26	0,09	0,14	0,62	0,95	0,62	0,95
09:00-09:59	0,09	0,07	0,05	0,04	0,12	0,18	0,06	0,09	0,62	0,95	0,35	0,54
10:00-10:59	0,07	0,05	0,04	0,03	0,09	0,14	0,05	0,07	0,62	0,95	0,27	0,42
11:00-11:59	0,09	0,07	0,04	0,03	0,11	0,17	0,06	0,09	0,62	0,95	0,33	0,51
12:00-12:59	0,10	0,07	0,05	0,04	0,12	0,19	0,06	0,10	0,62	0,95	0,38	0,58
13:00-13:59	0,10	0,07	0,05	0,04	0,12	0,19	0,06	0,10	0,62	0,95	0,38	0,59
14:00-14:59	0,13	0,10	0,07	0,05	0,17	0,26	0,09	0,14	0,62	0,95	0,62	0,95
15:00-15:59	0,16	0,12	0,08	0,06	0,20	0,31	0,11	0,17	0,62	0,95	0,62	0,95
16:00-16:59	0,16	0,13	0,09	0,07	0,20	0,31	0,11	0,17	0,62	0,95	0,62	0,95
17:00-17:59	0,13	0,10	0,06	0,05	0,16	0,24	0,08	0,13	0,62	0,95	0,56	0,86
18:00-18:59	0,08	0,06	0,04	0,03	0,11	0,17	0,05	0,08	0,62	0,95	0,32	0,50
19:00-19:59	0,05	0,04	0,03	0,02	0,07	0,11	0,03	0,05	0,43	0,67	0,23	0,35
20:00-20:59	0,04	0,03	0,02	0,02	0,05	0,08	0,03	0,04	0,32	0,50	0,19	0,29
21:00-21:59	0,04	0,03	0,02	0,01	0,05	0,07	0,02	0,03	0,28	0,43	0,16	0,25
22:00-22:59	0,02	0,02	0,01	0,01	0,03	0,04	0,01	0,02	0,18	0,28	0,10	0,15
23:00-23:59	0,01	0,01	0,01	0,00	0,01	0,02	0.01	0,01	0,12	0,18	0,06	0,09

Table 13. Calculated C_A and C_A/C_D values when 30 000 traveler uses NET. Notice that $C_D=0.65[m^3/m^2,S,P_a^n]$.

			PASSING PEOPLE 40 000 TRAVELERS												
			Entra	ances		C	ata		Occupa	ant loa	ıd				
		Stu	died	Ot	her	U.	ale	occupants	n	%	n	%			
		Weekdays Weekends		Weekdays	Weekends	Weekdays	Weekends	weekdays			weekends				
00:00-00:59	0%	84,36	42,18	11,36	5,68	6,46	3,23	129,79	15,15	0,03	7,57	0,01			
01:00-01:59	0%	25,92	12,96	3,49	1,74	1,98	0,99	39,87	4,65	0,01	2,33	0,00			
02:00-02:59	0%	1,76	0,88	0,24	0,12	0,13	0,07	2,71	0,32	0,00	0,16	0,00			
03:00-03:59	0%	1,47	0,74	0,20	0,10	0,11	0,06	2,27	0,26	0,00	0,13	0,00			
04:00-04:59	0%	37,33	18,67	5,03	2,51	2,86	1,43	57,43	6,70	0,01	3,35	0,01			
05:00-05:59	1%	376,40	188,20	50,67	25,33	28,81	14,40	579,08	67,58	0,12	33,79	0,06			
06:00-06:59	4%	1175,24	587,62	158,21	79,10	89,94	44,97	1808,06	211,00	0,38	105,50	0,19			
07:00-07:59	11%	3059,20	1529,60	411,82	205,91	234,13	117,06	4706,46	549,24	1,00	274,62	0,50			
08:00-08:59	8%	2342,30	1171,15	315,31	157,65	179,26	89,63	3603,54	420,53	0,77	210,27	0,38			
09:00-09:59	5%	1539,13	769,57	207,19	103,60	117,79	58,90	2367,90	276,33	0,50	138,17	0,25			
10:00-10:59	4%	1191,41	595,70	160,38	80,19	91,18	45,59	1832,94	213,90	0,39	106,95	0,19			
11:00-11:59	5%	1449,25	724,63	195,09	97,55	110,92	55,46	2229,62	260,20	0,47	130,10	0,24			
12:00-12:59	6%	1636,96	818,48	220,36	110,18	125,28	62,64	2518,39	293,90	0,54	146,95	0,27			
13:00-13:59	6%	1651,13	825,56	222,27	111,13	126,37	63,18	2540,20	296,44	0,54	148,22	0,27			
14:00-14:59	8%	2317,09	1158,55	311,92	155,96	177,33	88,67	3564,76	416,01	0,76	208,00	0,38			
15:00-15:59	10%	2859,32	1429,66	384,91	192,45	218,83	109,42	4398,96	513,36	0,93	256,68	0,47			
16:00-16:59	10%	2913,96	1456,98	392,26	196,13	223,01	111,51	4483,02	523,17	0,95	261,58	0,48			
17:00-17:59	7%	2173,95	1086,98	292,65	146,32	166,38	83,19	3344,54	390,31	0,71	195,15	0,36			
18:00-18:59	5%	1422,62	711,31	191,51	95,75	108,88	54,44	2188,65	255,42	0,47	127,71	0,23			
19:00-19:59	3%	911,97	455,99	122,77	61,38	69,80	34,90	1403,03	163,73	0,30	81,87	0,15			
20:00-20:59	2%	710,00	355,00	95,58	47,79	54,34	27,17	1092,31	127,47	0,23	63,74	0,12			
21:00-21:59	2%	600,10	300,05	80,78	40,39	45,93	22,96	923,24	107,74	0,20	53,87	0,10			
22:00-22:59	1%	347,68	173,84	46,80	23,40	26,61	13,30	534,89	62,42	0,11	31,21	0,06			
23:00-23:59	1%	207,58	103,79	27,94	13,97	15,89	7,94	319,35	37,27	0,07	18,63	0,03			
People per	day	29036,15	14518,08	3908,71	1954,36	40000,00	20000,00	44671,00	549,24						

Table 14. Occupant load for each entrance when 40 000 traveler uses NET.

	SETTINGS 40 000 TRAVELERS												
Timo		Ga	ate			Entra	ances		Studied entrance				
Time	Weekdays		Weekends		Weekdays		Weekends		We	ekdays	We	ekends	
	CA	CA/CD	CA	CA/CD	CA	CA/CD	CA	CA/CD	CA	CA/CD	CA	CA/CD	
00:00-00:59	0,01	0,00	0,00	0,00	0,01	0,01	0,00	0,00	0,06	0,10	0,03	0,05	
01:00-01:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,03	0,01	0,01	
02:00-02:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
03:00-03:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
04:00-04:59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,04	0,01	0,02	
05:00-05:59	0,03	0,02	0,01	0,01	0,04	0,06	0,02	0,03	0,24	0,37	0,13	0,21	
06:00-06:59	0,09	0,07	0,05	0,04	0,11	0,18	0,06	0,09	0,62	0,95	0,35	0,53	
07:00-07:59	0,22	0,17	0,12	0,09	0,26	0,40	0,15	0,22	0,62	0,95	0,62	0,95	
08:00-08:59	0,17	0,13	0,09	0,07	0,21	0,32	0,11	0,18	0,62	0,95	0,62	0,95	
09:00-09:59	0,12	0,09	0,06	0,05	0,15	0,22	0,08	0,12	0,62	0,95	0,49	0,75	
10:00-10:59	0,09	0,07	0,05	0,04	0,12	0,18	0,06	0,09	0,62	0,95	0,35	0,54	
11:00-11:59	0,11	0,09	0,06	0,04	0,14	0,21	0,07	0,11	0,62	0,95	0,45	0,69	
12:00-12:59	0,13	0,10	0,06	0,05	0,15	0,24	0,08	0,12	0,62	0,95	0,53	0,82	
13:00-13:59	0,13	0,10	0,07	0,05	0,16	0,24	0,08	0,13	0,62	0,95	0,54	0,83	
14:00-14:59	0,17	0,13	0,09	0,07	0,21	0,32	0,11	0,17	0,62	0,95	0,62	0,95	
15:00-15:59	0,21	0,16	0,11	0,09	0,25	0,38	0,14	0,21	0,62	0,95	0,62	0,95	
16:00-16:59	0,21	0,16	0,11	0,09	0,25	0,38	0,14	0,21	0,62	0,95	0,62	0,95	
17:00-17:59	0,16	0,12	0,09	0,07	0,20	0,30	0,11	0,16	0,62	0,95	0,62	0,95	
18:00-18:59	0,11	0,08	0,06	0,04	0,14	0,21	0,07	0,11	0,62	0,95	0,44	0,67	
19:00-19:59	0,07	0,06	0,04	0,03	0,09	0,14	0,05	0,07	0,62	0,95	0,27	0,42	
20:00-20:59	0,06	0,04	0,03	0,02	0,07	0,11	0,03	0,05	0,43	0,67	0,23	0,36	
21:00-21:59	0,05	0,04	0,02	0,02	0,06	0,09	0,03	0,05	0,35	0,55	0,20	0,31	
22:00-22:59	0,03	0,02	0,01	0,01	0,03	0,05	0,02	0,02	0,23	0,35	0,12	0,19	
23:00-23:59	0,02	0,01	0,01	0,01	0,02	0,03	0,01	0,01	0,15	0,23	0,08	0,12	

Table 15. Calculated C_A and C_A/C_D values when 40 000 traveler uses NET. Notice that $C_D=0.65[m^3/m^2,S,P_a^n]$.

Appendix C: Evaluation of optimized solutions for NET

The purpose of the evaluation was to identify the most optimized solutions for NET based on the parameter study. Three criteria were chosen and evaluated against each other which resulted in a percentage of importance for each criterion. The chosen criteria were heating consumption, cooling consumption and mean indoor temperature. Each possible solution was then evaluated with respect to the chosen criteria and scored with a number from 1-5. The score was then multiplied with the percentage of importance and summarized for each solution. The solution with the highest score was then chosen. Tables below show the evaluation between the criteria and the results for each study case.

		Heating cons.	Cooling cons.	Indoor temp.	Score
- y -	43,80%	1	1	1	1,00
stud	28,80% (Ref)	2	3	2	2,33
v. s Ame	22,70%	3	4	3	3,33
En	17,40%	4	2	4	3,33
	g=0,1	1	5	3	2,67
idy ince ie	g=0,26 (Ref)	2	4	3	2,83
stu rma valu	g=0,3	3	3	3	3,00
Env. perfo. g-	g=0,35	4	2	3	3,17
	g=0,4	5	1	3	3,33
y - ce:	U=0,4	4	1	3	2,83
tud nan alue	U=1,1	3	2	3	2,67
v. s forr J-v;	U=1,65(Ref)	2	3	2	2,33
En	U=2,0	1	4	1	2,00
u	0º (Ref)	2	4	0	2,33
ltatc dy	90°	4	3	0	3,00
rien stu	180°	1	1	0	0,83
Ö	270°	3	2	0	2,17
• ~	Reference	2	1	2	1,67
/ent tudy	No ventilation	3	2	1	2,33
► 50	Recirculation	1	3	2	1,83
nce	Reference	1	4	1	2,00
ions	All swing vestibule 90	3	3	2	2,83
al er olut	All entrances revolving	4	1	3	2,83
Ide:	All revolving	4	2	4	3,33

	Heating cons.	Cooling cons.	Indoor temp.	Sum
Heating cons.	0	0	0	-
Cooling cons.	1	0	0	-
Indoor temp.	1	1	0	-
Sum	2	1	0	3
Corr. Sum	3	2	1	6
Procentage	50%	33%	17%	100%