Software Requirements Specification for Sun Catcher

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Contents

Revision History

Date	Version	Notes
Date 1	1.0	Notes
Date 2	1.1	Notes

1 Reference Material

This section records information for easy reference.

1.1 Table of Units

Throughout this document SI (Système International d'Unités) is employed as the unit system. In addition to the basic units, several derived units are used as described below. For each unit, the symbol is given followed by a description of the unit and the SI name.

symbol	unit	SI
$^\circ$	angle	degree
$'$	angle	-
k	mass	kilo
m	length	metre
W	power	Watt ($\mathrm{W} = \mathrm{J\,s^{-1}}$)

1.2 Table of Symbols

The table that follows summarizes the symbols used in this document along with their units. The choice of symbols was made to be consistent with the heat transfer literature and with existing documentation for solar water heating systems. The symbols are listed in alphabetical order.

symbol	unit	description
$\theta_{S_{day}}$	$^\circ$	zenith angle of sun in the day
θ_T	$^\circ$	the tilt angle for adjusting the solar panel
Φ_P	($^\circ$ $'$)N/S	the latituade of the solar panel
δ_{date}	$^\circ$ N/S	the declination of the vertical noon sun in the day
$I_{S_{day}}$	$\frac{\mathrm{kW}}{\mathrm{m}^2}$	the intensity of the sun in a day of the noon
I_S	$\frac{\mathrm{kW}}{\mathrm{m}^2}$	the solar intensity in a period of days of the noon
P_E	kW	the estimated solar panel output energy
P_A	m^2	the solar panel area
P_r	%	solar panel yield or efficiency
PR	%	performance ratio, coefficient for losses
date	-	is a sequence of dates from the day starts estimating the angle to the ending day

1.3 Abbreviations and Acronyms

symbol	description
A	Assumption
DD	Data Definition
GD	General Definition
GS	Goal Statement
IM	Instance Model
LC	Likely Change
PS	Physical System Description
R	Requirement
SRS	Software Requirements Specification
SC	Sun Catcher
T	Theoretical Model

2 Introduction

Due to the increasing concepts of creating an earth-friendly environment, the kits using renewable energy becomes more popular in the market. Solar energy is the most common type of renewable resource for a home. However, it is an expensive technology, and its cell efficiency is restricted by seasons. Therefore, Sun Catcher is created for home users to gain optimum energy from daily sunlight.

The following sections provide an overview of the Software Requirements Specification (SRS) for Sun Catcher(SC). This section explains the purpose and the organization of the document, the scope of the requirements, and the characteristics of the intended reader.

2.1 Purpose of Document

The purpose of this document is to record the correct requirements of SC. The goal statement provided readers a consistent idea of what problem is solved. The theoretical models and the instance models, which state the mathematical terms supporting the theoretical models, are explained unambiguously for readers to reuse and verify the software. In the section of System Constraints, its contents will stay abstract because the content should only say what problem is being solved, but not how to solve it.

This document will be used as a starting point for subsequent development phases, including writing the design specification and the software verification and validation plan. The design document will show how the requirements are to be realized, including decisions on the numerical algorithms and programming environment. The verification and validation plan will show the steps that will be used to increase confidence in the software documentation and the implementation.

2.2 Scope of Requirements

The scope of the requirements includes stability analysis of a two-dimensional (2D) solar panel and the sun as the solar resource. The solar panel is assumed to place in a location near sea level, and the sky view above is unobstructed, with no trees, hills, clouds, dust, or haze ever blocking the sun.

2.3 Characteristics of Intended Reader

This section summarized the expectation of the readers' knowledge and skills for understanding this SRS. Readers should have a general knowledge of how a solar panel works and know the common factors that affect energy absorption.

2.4 Organization of Document

The organization of this document follows the template for an SRS for scientific computing software proposed by Koothoor [4] as well as Smith and Lai [8]. The presentation follows the standard pattern of presenting goals, theories, definitions, and assumptions. For readers that would like a more bottom up approach, they can start reading the instance models in Section: Instance Models) and trace back to find any additional information they require. The goal statements (Section: Goal Statements) are refined to the theoretical models and the theoretical models (Section: Theoretical Models) to the instance models (Section: Instance Models). The instance models provide the set of algebraic equations that must be solved.

3 General System Description

This section provides general information about the system. It identifies the interfaces between the system and its environment, describes the user characteristics and lists the system constraints.

3.1 System Context

System Context shows the design pattern of this program from users to the system than the output. The circle represents the users of this software. The rectangle represents the software system: Sun Catcher. The arrow represents the inputs that drive the software and the output expecting from the software.

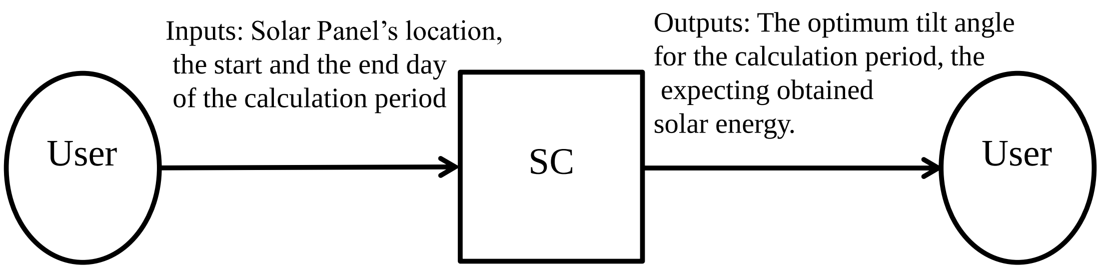

Figure 1: System Context

- User Responsibilities:
  - Provide the input data related to the solar panel.
  - Ensure the input date format matches the requirement from SC.
  - Ensure the condition of the solar panel, and the surrounding environment of the solar panel.
- SC Responsibilities:
  - Detect data type mismatch, such as a string of characters instead of a floating point number.
  - Comfirm the inputs quality to satisfy the required physical and software constraints.
  - Predict an optimum tilt angle, the expected gaining solar energy, and a report that shows the comparison of different results.

3.2 User Characteristics

The end-users of SC is expecting to understand the Level 1 Calculation method such as angle addition and subtraction theorems and understand the Level 1 celestial mechanics such as the formation of the latitude and the earth's tilt angle in the four seasons.

3.3 System Constraints

There are no system constraints.

4 Specific System Description

This section first presents the problem description, which gives a high-level view of the problem to be solved. This is followed by the solution characteristics specification, which presents the assumptions, theories, definitions and finally the instance models.

4.1 Problem Description

Sun Catcher is intended to solve the unpredictable energy efficiency of solar panels. Due to the tilt angle of the earth when it rotates by axis, the latitude of the sun will consistently move. With the fixed location of the solar panel, it is unlikely to get the direct the direct sunlight for the maximum output. Therefore, it causes inadequate performance in gaining energy.

4.1.1 Terminology and Definitions

This subsection provides a list of terms that are used in the subsequent sections and their meaning, with the purpose of reducing ambiguity and making it easier to correctly understand the requirements:

- Declination of the Sun: The angle between the rays of the Sun and the plane of the Earth's equator.
- Tilt angle: The angle for adjusting the solar panel result in the panel get the direct sunlight. According to the Figure:The Physic System, tilt angle is equal to the zenith angle.
- The period of days: The period of days depends on the input days of the users.
- Sun panel: The adjustable panel, which has solar cells on it, able to converse solar energy to power.
- Sun Intensity: The amount of incoming solar energy, or radiation, that reaches the Earth's surface.

- Latitude: Latitude is an angle which ranges from 0 ° at the Equator to 90° (North or South) at the poles.
- Zenith Angle: The angle between the sun and the vertical. According to the Figure:The Physic System, zenith angle is equal to the tilt angle.

4.1.2 Physical System Description

The physical system of SC, as shown in Figure: *ThePhysicSystem*, includes the following elements:

PS1: Solar Panel: The panel with solar cell that able to absorb solar energy from sun.

PS2: Sun: Proving solar energy to solar panel

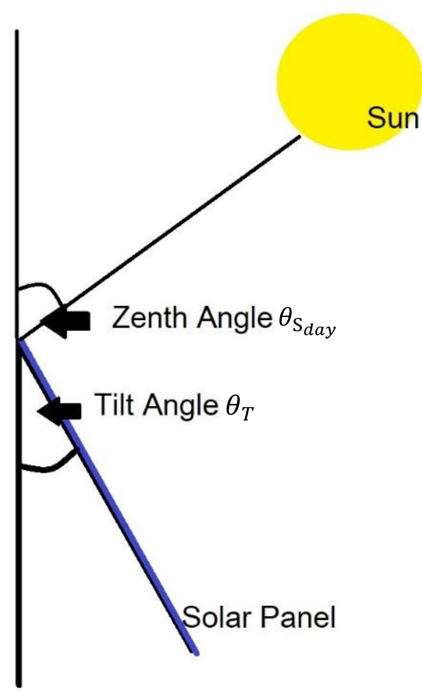

Figure 2: The Physic System

4.1.3 Goal Statements

Given the user located latitude, the day started to estimate angle,the day when the estimation end, the goal statements are:

GS1: Predict the optimum tilt angle in the period of days.

GS2: Predict the optimum produced solar energy in the period of days.

GS3: Predict the possibility the amount of money user might save.

4.2 Solution Characteristics Specification

The instance models that govern SC are presented in Section: Instance Models. The information to understand the meaning of the instance models and their derivation is also presented, so that the instance models can be verified.

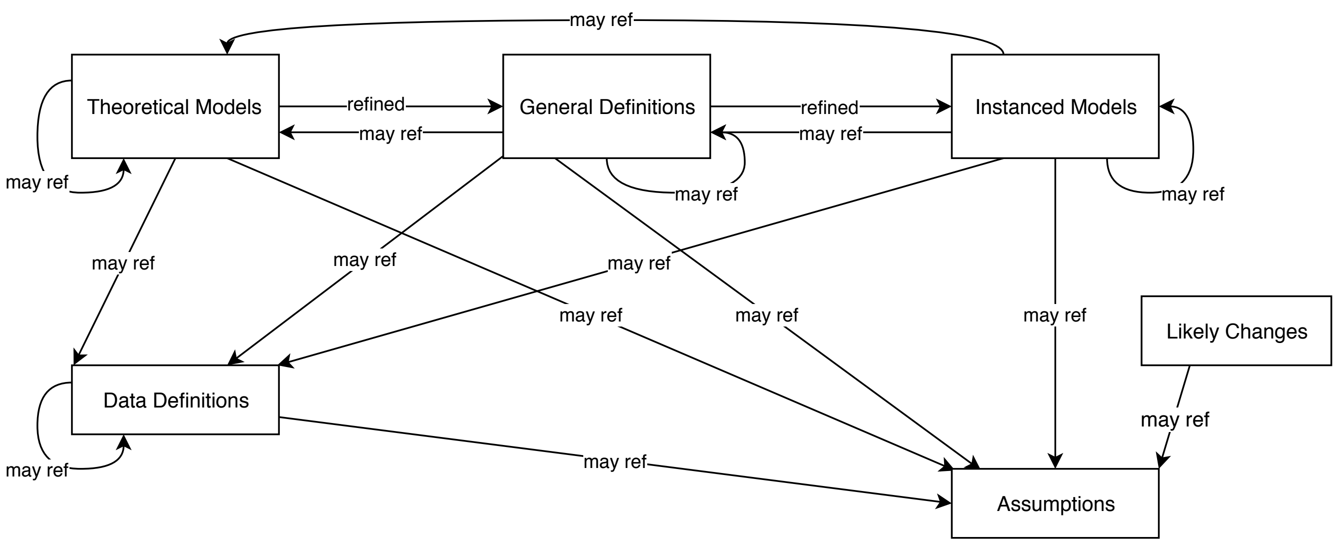

Figure 3: Models' Relations

The instance models that govern SC are presented in Subsection 4.2.5. The information to understand the meaning of the instance models and their derivation is also presented, so that the instance models can be verified.

4.2.1 Assumptions

This section simplifies the original problem and helps in developing the theoretical model by filling in the missing information for the physical system. The numbers given in the square brackets refer to the theoretical model [T], general definition [GD], data definition [DD], instance model [IM], or likely change [LC], in which the respective assumption is used.

A1 : The environmental condition of the solar panel location assumed as users have an unobstructed view of the sky, with no trees, hills, clouds, dust, or haze ever blocking the sun.(RefBy: IM1)

A2 : The default solar intensity is 1.35 kW. It was measured by the satellites.(RefBy: IM1)

A3 : This system calculate the solar zenith angle at noon.(RefBy: GD1)

A4 : Based on the resource of for Materials Science and (EMPA), this system definite the variable of P_r as 18.7%.(RefBy: IM3)

4.2.2 Theoretical Models

This section focuses on the general equations and laws that SC is based on.

Number	T1
Label	**Lambert's cosine law**
Equation	$I_0 = I \times \frac{\cos\theta \times \partial\Omega \times \partial A}{\cos\theta \times \partial\Omega_0 \times \partial A_0}$
Description	In the following source, Lambert's cosine law state that "the radiant intensity or luminous intensity observed from an ideal diffusely reflecting surface or ideal diffuse radiator is directly proportional to the cosine of the angle θ between the direction of the incident light and the surface normal." I_0 is the radiance of illumination. I is the number of the photons. $\cos\theta \times \partial\Omega \times \partial A$is the number of photo ns per second emitted into the wedge at angle θ where $\partial\Omega$is an equal angle that represents each wedge in the circle. ∂A is the area element . $\partial\Omega_0$ is the portion of the observer's total angular field-of-view of the scene. ∂A_0 is an aperture of area .
Source	Weik (2000)
Ref. By	RefBy: IM1

4.2.3 General Definitions

This section collects the laws and equations that will be used in building the instance models.

Number	GD1
Label	**Calculate Zenith Angle**
SI Units	$\circ$
Equation	$$\theta_{S_{day}} = \begin{cases} \Phi_P - \delta_{date}, & \text{if } 0 \leq \Phi_P, \delta_{date} \leq 90°\text{N} \ \vee \ 0 \leq \Phi_P, \delta_{date} \leq 90°\text{S} \\ \Phi_P + \delta_{date}, & \text{if } \begin{cases} 0 \leq \Phi_P \leq 90°\text{N} \ \wedge \ 0 \leq \delta_{date} \leq 90°\text{S} \\ 0 \leq \Phi_P \leq 90°\text{S} \ \wedge \ 0 \leq \delta_{date} \leq 90°\text{N} \end{cases} \end{cases}$$
Description	This equation describes the zenith angle associated with the solar panel. $\theta_{S_{day}}$ is the zeith angle of the sun in the day. Φ_P is the local latitude of the solar panel. δ_{date} is the declination of the vertical noon sun in the day.
Source	Woolf (1968)
Ref. By	DD1

Detailed derivation of simplified rate of change of temperature

According to the resource Woolf (1968), it states the the solar elevation angle $\sin\alpha$ is determined by the relationship
$\sin\alpha = \sin\Phi \times \sin\delta + \cos\Phi \times \cos\delta \times \cos \mathrm{h}$
where
α is the solar elevation.
Φ is the latituade.
δ is the solar declination.
h is the solar hour angle.
Based on the Level 1 celestial mechanics, the solar zenith angle is equal to 90° - the solar elevation angle
which can write as

$\cos\theta = \sin\alpha = \sin\Phi \times \sin\delta + \cos\Phi \times \cos\delta \times \cos \mathrm{h}$ Based on the Assumptions section, it assumes that SC calculate the solar zenith angle at noon which mean solar hour angle = 0°. Therefore, $\cos \mathrm{h} = 0$
Rewrite the equation as,
$\cos\theta = \sin\alpha = \sin\Phi \times \sin\delta + \cos\Phi \times \cos\delta \times 1$
$\Rightarrow \cos\theta = \sin\alpha = \sin\Phi \times \sin\delta + \cos\Phi \times \cos\delta$
Based on the Level 1 calcucltion, we have
$\cos\Phi \pm \delta = \sin\alpha = \sin\Phi \times \sin\delta + \cos\Phi \times \cos\delta$
Therefore, we have $\theta = \Phi \pm \delta$

4.2.4 Data Definitions

This section collects and defines all the data needed to build the instance models. The dimension of each quantity is also given.

Number	DD1
Label	**The Declination of the Sun**
Symbol	δ_{date}
SI Units	°
Equation	-
Description	"date" means every date in the period of days which depends on the user's input. The degree of δ_{date} can be determinated by the the Analemma Figure.
Sources	https://www.cengage.com/resource_uploads/downloads/0495555061_137179.pdf
Ref. By	GD1

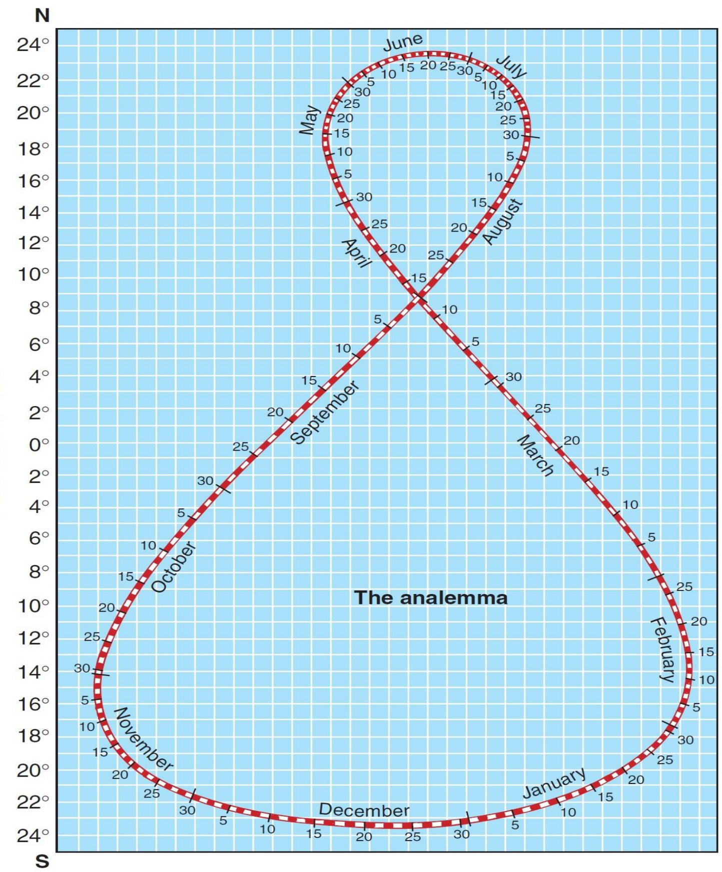

Figure 4: Analemma

4.2.5 Instance Models

This section transforms the problem defined in Section 4.1 into one which is expressed in mathematical terms. It uses concrete symbols defined in Section 4.2.4 to replace the abstract symbols in the models identified in Sections 4.2.2 and 4.2.3.

The goals Goal Statements are solved by IM1.

Number	IM1
Label	**Calculating the Sun intensity**
Input	$\Phi_P, date$
Output	$I_{S_{day}} = 1.35 \cdot \frac{1.00}{1.35}^{sec(\theta_{S_{day}})}$
Description	As the *Assumptions* describes, this equation is giveing the daily sun intensity at noon. Moreover, this equation assumes that the earth is flat, so a factor was applied to account for the curvature of the earth(and therefore the earth's atmosphere). These factors, and the angle of the sun with respect to the panel, then determine the insolation on the panel. $(\theta_{S_{day}})$ is the zenith angle of the sun in the day. The equation of $(\theta_{S_{day}})$ is described in $GD1$.
Sources	https://www.solarpaneltilt.com/#other
Ref. By	IM2

Derivation of ...

The above equation is driven by the $T1$, which is describing the calculation of the radiance of the illumination.
Where I is $1.35k$W, which is the solar intensity, and $\frac{1}{\cos\theta}$ is $sec(\theta_{S_{day}})$

Number	IM2
Label	**Calculating the Tilt Angle**
Input	$\theta_{S_{day}}, I_{S_{day}}$
Output	I_T, I_S
Description	Using Instance Model IM1 can get a angle to adjust the solar panel and the sun itensity for each date in the period of days. Then using Iteration Method to calculate to optimum angle and the sun itensity for the period of days.
Sources	https://www.solarpaneltilt.com/#other
Ref. By	IM3

Number	IM3
Label	**Calculating the Solar Energy Output**
Input	P_A
Output	$P_E = P_A \times P_r \times I_S \times PR$
Description	P is the solar panel. P_E is the estimated solar panel output energy. P_A is the solar panel area. P_r is solar panel yield or efficiency. I_S is the solar intensity in a period of days of the noon. PR is the performance ratio, coefficient for losses
Sources	https://photovoltaic-software.com/principle-ressources/how-calculate-solar-energy-power-pv-systems
Ref. By	-

Derivation of ...

The above equation is using the output from $IM1$, which is describing the sun intensity. Some of the variable in this equation has its defult value, which describes in the section of *Assumptions*

4.2.6 Input Data Constraints

Table 1 shows the data constraints on the input output variables. The column for physical constraints gives the physical limitations on the range of values that can be taken by the variable. The column for software constraints restricts the range of inputs to reasonable values. The software constraints will be helpful in the design stage for picking suitable algorithms. The constraints are conservative, to give the user of the model the flexibility to experiment with unusual situations. The column of typical values is intended to provide a feel for a common scenario. The uncertainty column provides an estimate of the confidence with which the physical quantities can be measured. This information would be part of the input if one were performing an uncertainty quantification exercise.

The specification parameters in Table 1 are listed in Table 2.

Table 1: Input Variables

Var	Physical Constraints	Software Constraints	Typical Value	Uncertainty
Φ_P	$0 \leq \Phi_P \leq 90°$N/S	-	43°15'39.3"N	10%

Table 2: Specification Parameter Values

Var	Value
-	-

4.2.7 Properties of a Correct Solution

Table:$OutputVariables$ shows the data constraints on the output variables. The column for physical constraints gives the physical limitations on the range of values that can be taken by the variable.

Table 3: Output Variables

Var	Physical Constraints
θ_{tilt}	$0 \leq \theta_{tilt} \leq 90°$ (by A??)
P_E	$0 \leq P_E \leq$ Rated Maximum Power (by A??)

Rated Maximum Power is measured by manufacturers which shows the maximum power the solar panel can generate.

5 Requirements

This section provides the functional requirements, the business tasks that the software is expected to complete, and the nonfunctional requirements, the qualities that the software is expected to exhibit.

5.1 Functional Requirements

R1: Input the values requested by the system, which is the latitude of the solar panel, the date starts the calculation and the ending date.

R2: Output the valid values for the problem defined by $ProblemDescription$, which is the optimum tilt angle for solar panel, the predicted solar energy output.

R3: Determine the tilt angle by using $IM1$ and the solar energy output by using $IM3$

R4: Verify the output by using the Table: $OutputVariables$

5.2 Nonfunctional Requirements

This section provides the non-functional requirements, the qualities that the software is expected to exhibit.

Correct: The outputs of the code have the properties described in Section: Properties of a Correct Solution

Verifiable: The code is tested with complete verification and validation plan

Understandable: The code is modularized with complete module guide and module interface specification

Reusable: The code is modularized

Maintainable: The traceability between requirements, assumptions, theoretical models, general definitions, data definitions, instance models, likely changes, unlikely changes, and modules is completely recorded in traceability matrices in the SRS and module guide

Portable: The code is able to be run in different environments

6 Likely Changes

LC1: The system currently using the latest data of the solar's intensity, the calculation can be modified if this data upgrade in the future.$A3$

LC2: The system currently using the latest data of the solar panel's efficiency, the calculation can be modified if this data upgrade in the future.$A4$

7 Unlikely Changes

LC3: The goal of the system is to predict the optimum tilt energy without considering the individual environmental difference from each case.A1

8 Traceability Matrices and Graphs

The purpose of the traceability matrices is to provide easy references on what has to be additionally modified if a certain component is changed. Every time a component is changed, the items in the column of that component that are marked with an "X" may have to be modified as well. Table 4 shows the dependencies of theoretical models, general definitions, data definitions, and instance models with each other. Table 5 shows the dependencies of instance models, requirements, and data constraints on each other. Table 6 shows the dependencies of theoretical models, general definitions, data definitions, instance models, and likely changes on the assumptions.

[You will have to modify these tables for your problem. —TPLT]

[The traceability matrix is challenging to maintain manually. Please do your best. In the future tools (like Drasil) will make this much easier. —TPLT]

	T1	GD1	DD1	IM1	IM3
T1					
GD1					
DD1					
IM1	X	X	X		
IM2				X	
IM3				X	

Table 4: Traceability Matrix Showing the Connections Between Items of Different Sections

	IM1	IM2	IM3	4.2.6	R1	R2	R3	R4	R5
IM1				X	X				
IM2	X						X		X
IM3		X					X		X
R1	X	X		X		X			
R2	X	X	X						
R3	X	X	X						
R4	X	X	X						
R5	X	X	X						

Table 5: Traceability Matrix Showing the Connections Between Requirements and Instance Models

The purpose of the traceability graphs is also to provide easy references on what has to be additionally modified if a certain component is changed. The arrows in the graphs represent dependencies. The component at the tail of an arrow is depended on by the component at the head of that arrow. Therefore, if a component is changed, the components that it points to should also be changed. Figure 3 shows the dependencies of theoretical models, general definitions, data definitions, instance models, likely changes, and assumptions on each other.

9 Values of Auxiliary Constants

There are no auxiliary constants.

	A1	A2	A3	A4
T1				
GD1			X	
DD1			X	
IM1	X	X	X	
IM2				
IM3				X
LC1		X		
LC2				X
LC3	X			

Table 6: Traceability Matrix Showing the Connections Between Assumptions and Other Items

References

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Martin Weik. *Lambert's cosine law. In: Computer Science and Communications Dictionary.* Kluwer Academic Publishers 2000, Springer US., 1nd edition, 2000.

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