1 System Requirements Specification

The requirements specifications are detailed in the following sections:

1.1 – Simulator

1.2 – Simulator-Controller Interface

1.3 – Simulation Log file

1.4 – Simulation Input Data file

1.5 - Simulation-Log Player

1.1 Simulator

Identifier	Sys-SI-FR-01
Title	Real-world elements to be simulated.
Description	The real-world elements that participate of a simulation are: • multi-lane streets, blocks, intersections, • traffic lights, • vehicles.
Rationale	
Depends on:	
Decomposed by:	

Identifier	Sys-SI-FR-02
Title	Physical characteristics of the AoA
Description	The geographical area of interest in a simulation (AoA = Area of Actuation) is composed of multi-lane one-way streets, and intersections. The configuration of the AoA to be used in a given simulation is described by a file (Simulation Data Input File - Sys-SI-IR-02).
Rationale	
Depends on:	Sys-SI-IR-02
Decomposed by:	

Identifier	Sys-SI-FR-03
Title	Behavior of simulated vehicles.
Description	The behavior of the simulated vehicles is ruled by: • Safety rules concerning traffic lights, traffic direction, distance between consecutive vehicles, capacity of each block. • Rules of vehicle movement concerning their speed. • Rules of turning concerning the path of a vehicle through the AoA. • Boundary rules concerning the behavior of the vehicle when crossing the AoA border.
Rationale	
Depends on:	
Decomposed by:	Sys-SI-FR-03.1, Sys-SI-FR-03.2, Sys-SI-FR-03.3, Sys-SI-FR-03.4, Sys-SI-FR-03.5, Sys-SI-FR-03.6, Sys-SI-FR-03.7

Identifier	Sys-SI-FR-03.1
Title	Behavior of simulated vehicles – Safety Rule – Traffic Light
Description	The behavior of the simulated vehicles arriving at an intersection is determined by the state of the corresponding traffic light: • If the traffic light is red the vehicle must stop in the block before the intersection. • If the light is green and there is space in the following block then the vehicle may proceed. • During the first two seconds of a yellow light the vehicle behaves as if the light was green. • During the remaining time (after the initial two seconds) of yellow light the vehicle behaves as if the light was red.
Rationale	
Depends on:	
Decomposed by:	

Identifier	Sys-SI-FR-03.2
Title	Behavior of simulated vehicles – Safety Rule – Traffic Direction
Description	The direction of movement of a simulated vehicle must be the same as the direction of the lane it is traveling on.
Rationale	
Depends on:	
Decomposed by:	

Identifier	Sys-SI-FR-03.3
Title	Behavior of simulated vehicles – Safety Rule – Distance between consecutive vehicles.
Description	The minimum distance between two consecutive vehicles traveling on the same lane is 1 m.
Rationale	
Depends on:	
Decomposed by:	

Identifier	Sys-SI-FR-03.4
Title	Behavior of simulated vehicles – Safety Rule – Capacity of a block
Description	A block has a capacity of 25 vehicles per lane.
Rationale	Considering the length of a vehicle as 3m and the minimum distance between vehicles of 1 m then in a block of 100m in length there is space for 25 vehicles in each lane.
Depends on:	Sys-SI-FR-03.3
Decomposed by:	

Identifier	Sys-SI-FR-03.5
Title	Behavior of simulated vehicles – Vehicle Movement Rule
Description	When it is safe to move (see Safety Rules above) a vehicle moves at the speed of 20 m/s (72 km/h).
Rationale	
Depends on:	Sys-SI-FR-03.1, Sys-SI-FR-03.2, Sys-SI-FR-03.3
Decomposed by:	

Identifier	Sys-SI-FR-03.6
Title	Behavior of simulated vehicles – Rules of Turning
Description	Each block in the AoA has an associated probability of turn (T). The simulated behavior of vehicles approaching an intersection is that every Nth vehicle in a sequence will turn into the crossing street, where N is given by:

T	N		16-20%	5
1-5%	20		21-35%	3
6-10%	10		36%-50%	2
11-15%	7			

Rationale	
Depends on:	
Decomposed by:	

Identifier	Sys-SI-FR-03.7
Title	Behavior of simulated vehicles – Boundary Rules
Description	A vehicle buffer exists whenever a street crosses the AoA boundary. At the start of the street (beginning of the flow of vehicles) there is an entry-buffer and at the end of the street there is an exit-buffer. Each simulation scenario (described in Simulation Data Input File - Sys-SI-IR-02) states when a vehicle is inserted in an entry-buffer. Vehicles leave an entry-buffer as soon as there is space in the first block of the corresponding street. Vehicles that enter an exit-buffer do not leave it.
Rationale	
Depends on:	Sys-SI-IR-02
Decomposed by:	

1.2 Simulator-Controller Interface

Identifier	Sys-CO-IR-01
Title	Simulator-Controller Interface Structure
Description	The Simulator-Controller interface is composed of two areas: • AoA status area that indicates the amount of vehicles in each block • Semaphores control area that controls the state of each semaphore in the AoA
Rationale	This structure allows the Controller to monitor the events of interest in the AoA and actuate on the semaphores to achieve its control objective.
Depends on:	
Decomposed by:	Sys-CO-IR-01.1, Sys-CO-IR-01.2

Identifier	Sys-CO-IR-01.1
Title	Simulator-Controller Interface Structure – Status Area
Description	The Simulator-Controller Interface Status Area contains a vector with the current state of occupancy of each block in the AoA, as determined by the corresponding sensors. Hence, the Status Area is written by the Simulator (based on the readings of the simulated sensors) and read by the Controller. • The vector's index is the block numeric identifier (Sys-SI-IR-01.2.5) • The vector's size is large enough to accommodate all block numeric identifiers, i.e. size = largest-block-numeric-identifier + 1. • Each entry in the vector occupies 1 byte to report the state of occupancy of that block: Light (0-60%) represented by the value 0, Heavy (60-99%) represented by the value 1, and Full (100%) represented by 2.
Rationale	
Depends on:	Sys-SI-IR-01.2.5
Decomposed by:	

Figure 1 depicts the state diagram of a semaphore. All transitions are commanded by the controller since it controls the value of all timing variables (Green1, Yellow1, Green2, Yellow2 and RedOverlap). The triggers change-to-TL1-Yellow and change-to-TL2-Yellow are used for synchronization among semaphores. The commands used by the Controller to specify the current state of a Semaphore are listed in the table below. A single byte is used.

TL1 refers to the Traffic Light on the NS street while TL2 refers to the one on the EW street.

Table 1 - Semaphore State Codes

State	Command
TL1-Green	0
TL1-Yellow	1
TL1-Red	2
TL2-Green	3
TL2-Yellow	4
TL2-Red	5

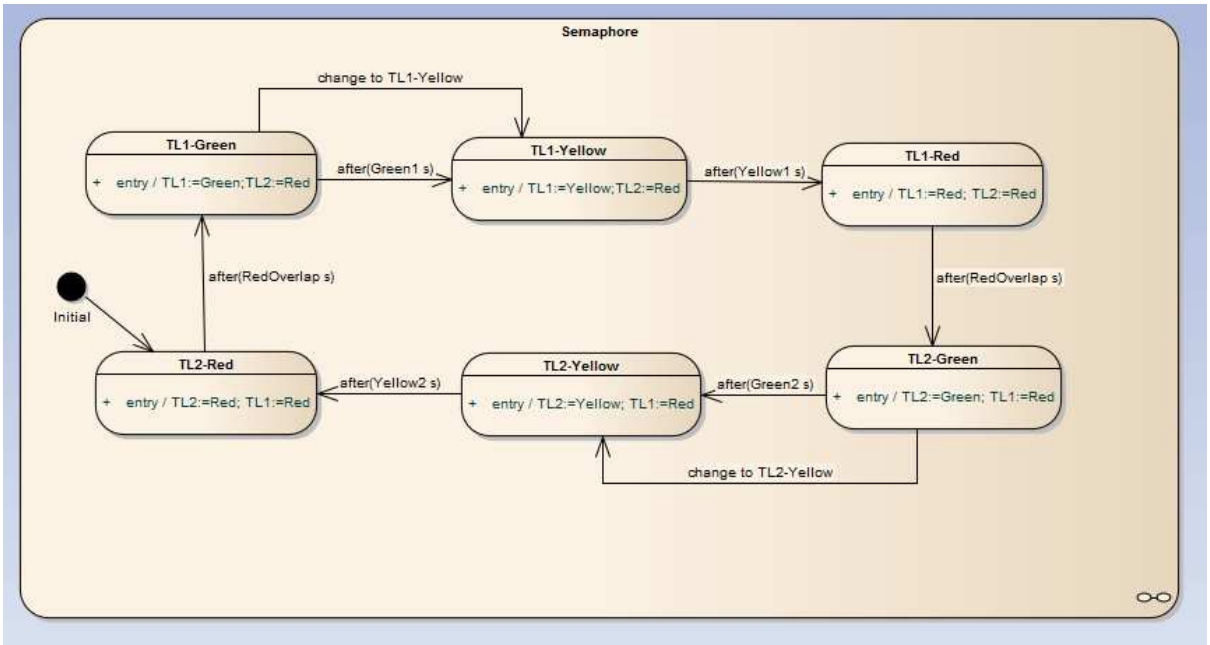

Figure 1 - Semaphore State Diagram

Identifier	Sys-CO-IR-01.2
Title	Simulator-Controller Interface Structure – Control Area
Description	The Simulator-Controller Interface Control Area contains a vector with the current state of each semaphore in the AoA. The control area is written by the Controller and read by the Simulator. • The vector's index is the intersection numeric identifier (Sys-SI-IR-01.2.4) • Each entry in the vector occupies 1 byte to specify the state of the semaphore (see Table 1).
Rationale	
Depends on:	Sys-SI-IR-01.2.4
Decomposed by:	

1.3 Simulation Log

Identifier	Sys-SI-IR-01
Title	Simulation log file format.
Description	The simulation log file is composed of an ASCII header, information on a simulation scenario and a binary list of events
Rationale	The simulation log file is the sole means of information exchange between the simulator and player. Hence, the log must include all the necessary information to allow a detailed playback of the simulation.
Depends on:	
Decomposed by:	Sys-SI-IR-01.1, Sys-SI-IR-01.2, Sys-SI-IR-01.3

Identifier	Sys-SI-IR-01.1
Title	Simulation log file format – ASCII header
Description	The ASCII header contains a single null-terminated string, coded in ASCII, with free text describing the contents of the log file.
Rationale	Since the remainder of the log file is in binary format, the ASCII header is the only section that is directly readable by the user to identify the contents of the file.
Depends on:	
Decomposed by:	

Identifier	Sys-SI-IR-01.2
Title	Simulation log file format – information field
Description	The information field consists of the following fields: • number-of-streets-in-AoA (coded in 2 bytes) • number-of-intersections-in-AoA (coded in 2 bytes • list-of-street-configurations (coded in 8 bytes per list item) • list-of-intersections (coded in 4 bytes per list item) • list-of-blocks • list-of-entry-points • list-of-exit-points
Rationale	The data in the information field is all the required information to reconstruct the physical layout of the streets and crossings of the AoA.
Depends on:	
Decomposed by:	Sys-SI-IR-01.2.1, Sys-SI-IR-01.2.2, Sys-SI-IR-01.2.3, Sys-SI-IR-01.2.4, Sys-SI-IR-01.2.5, Sys-SI-IR-01.2.6

Identifier	Sys-SI-IR-01.2.1
Title	Information Field format – number of streets
Description	The number of streets is coded as a 16-bit unsigned integer representing values from 0 to 65,535.
Rationale	The number of streets is required to interpret the length of the list-of-street-configurations.
Depends on:	
Decomposed by:	

Identifier	Sys-SI-IR-01.2.2
Title	Information Field format – number of intersections
Description	The number of intersections is coded as a 16-bit unsigned integer representing values from 0 to 65,535.
Rationale	The number of intersections is required to interpret the length of the list-of-intersections.
Depends on:	
Decomposed by:	

Identifier	Sys-SI-IR-01.2.3
Title	Information Field format – list of street configurations
Description	A list with number-of-streets-in-AoA entries where each entry has the following format (8 bytes / entry): • street numeric identifier (coded in 1 byte – 0..255) • street textual identifier (coded in 5 bytes – 5 ASCII chars) • number of lanes of this street (coded in 1 byte – 1..255) the value 0 is not allowed • direction of flow (coded in 1 byte – an enumeration with the values N→S (0), S→N (1), E→W (2), W→E (3)
Rationale	The numeric identifier is used as an index in other lists and tables. The textual identifier is used in human-readable text.
Comment	The format described here does not allow for streets where some lanes carry traffic in one direction while other lanes carry traffic in the opposite direction. Should we consider this scenario too ? R: I don´t think so, because we are not taking into consideration control rules that restrict the direction of a turn (only left or only right). That would be a reasonable restriction for a two-way street.
Depends on:	Sys-SI-IR-01.2.1
Decomposed by:	

Identifier	Sys-SI-IR-01.2.4
Title	Information Field format – list of intersections
Description	The number of entries in this list is given by the number of intersections. Each entry has the format (4 bytes/entry) • intersection numeric identifier (coded in 2 bytes – 0..65,535) • NS street numeric identifier (1 byte) – the street NS street • EW street numeric identifier (1 byte) – the street EW street
Rationale	
Depends on:	Sys-SI-IR-01.2.2
Decomposed by:	

Identifier	Sys-SI-IR-01.2.5
Title	Information Field format – list of blocks
Description	The number of entries in this list is calculated from the number of intersections. Each entry has the format (8 bytes/entry) • block numeric identifier (coded in 2 bytes – 0..65,535) • street numeric identifier (1 byte) – the street to which this block belongs • position in the street (1 byte) – the block with position 1 is the block adjacent to the entry point • intersection numeric identifier (coded in 2 bytes – 0..65,535) – the intersection at the end of the block • block capacity (1 byte) – maximum number of vehicles stopped at this block • percentage of turns (1 byte) – the percentage of cars that turn into the crossing street when they arrive at the end of this block.
Rationale	Listing of all blocks, their numeric identifications, the related street and intersection, its street position and its capacity. The percentage of turns is not required by the player but is required in the Input Data that uses the same format as described here.
Depends on:	Sys-SI-IR-01.2.2
Decomposed by:	

Identifier	Sys-SI-IR-01.2.6
Title	Information Field format – list of entry-points and list of exit-points
Description	The number of entry-points and exit points is calculated from the number of streets. Each entry has the following format: (4 bytes/entry) • street numeric identifier (1 byte) • position of entry/exit point (1 byte) – N (0), E (1), S(2), W (3) • capacity (2 bytes) – 0 to 65534 vehicles. Magic number 0xFFFF represents infinite capacity.
Rationale	
Depends on:	Sys-SI-IR-01.2.1
Decomposed by:	

Identifier	Sys-SI-IR-01.3
Title	Simulation log file format – List of Events
Description	The format of each entry (5 bytes) in the list of events is: • event identifier (1 byte) – (current-time (0), vehicle-p1-moving-in-block-p2 (1), vehicle-p1-stopped-in-block-p2 (2), vehicle-p1-in-entry-buffer-p2 (3), vehicle-p1-in-exit-buffer-p2 (4), semaphore-p1-in-state-p2 (5) • parameter 1 (2 bytes) – time (seconds field), vehicle identifier, or intersection identifier. • parameter 2 (2 bytes) – time (miliseconds field), block identifier, buffer identifier, or semaphore state (see Table 1). Remark: There is no explicit field stating the number of entries in the list of events, the list ends when the log file ends.
Rationale	
Depends on:	Sys-SI-IR-01.2.5
Decomposed by:	

The example below illustrates the format of the file for a very simple AoA with only 4 streets.

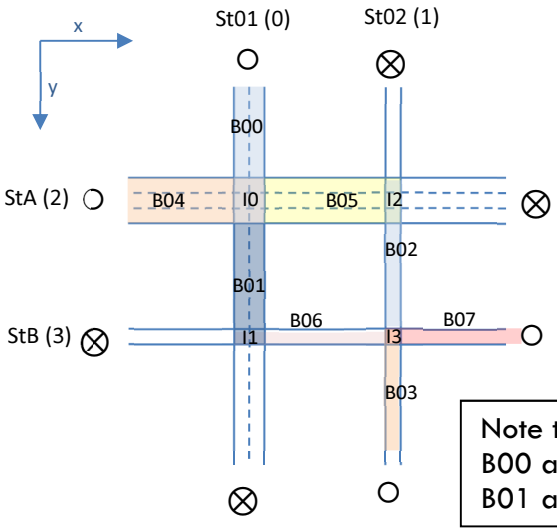

Figure 2 - Sample AoA

The numbering criteria used in this examples is:

Streets:

- Start numbering the blocks of the NS streets, from the upper-left corner (x,y) = (0,0).
- Number all blocks from the first NS street before moving to the next street.
- Numbering grows along the y axis.
- When all blocks on NS streets are done, proceed with the EW streets from top to bottom.
- Numbering of blocks grows along the x axis.

Intersections:

- Follow the same sequencing as the NS street blocks.

Sample simulation log file for a 2x2 AoA \0	ASCII header
0x0004	Number of streets
0x0004	Number of intersections
0x00 St01\0 2 0 0x01 St02\0 1 1 0x02 StA\0\0 3 3 0x03 StB\0\0 1 2	List of street configurations
0x0000 0 2 0x0001 0 3 0x0002 1 2 0x0003 1 3	List of Intersections
0x0000 0 1 00 50 10 0x0001 0 2 01 50 35 0x0002 1 2 02 25 20 0x0003 1 1 03 25 10 0x0004 2 1 00 75 10 0x0005 2 2 02 75 15 0x0006 3 2 01 25 15 0x0007 3 1 03 25 10	List of blocks
0 0 0xFFFF 1 2 0xFFFF 2 3 0xFFFF 3 1 0xFFFF	List of entry points
0 2 0xFFFF 1 0 0xFFFF 2 1 0xFFFF 3 3 0xFFFF	List of exit points
	List of Events
0 0 0	current time: 0 s 0 ms
3 0 0	vehicle 0 in entry buffer 0
3 1 2	
3 2 3	
3 3 3	
3 4 3	
0 1 0	current time 1s 0 ms
1 0 0	vehicle 0 moving in block 0
…	

1.4 Simulation Input Data File

Identifier	Sys-SI-IR-02
Title	Simulation input data file format.
Description	The simulation input data file is composed of an ASCII header, AoA configuration , initial simulation scenario and a binary list of events occurring at the AoA boundary along time.
Rationale	The simulation input data file provides all the required input for a simulation.
Depends on:	
Decomposed by:	Sys-SI-IR-02.1, Sys-SI-IR-02.2, Sys-SI-IR-02.3, Sys-SI-IR-02.4

Identifier	Sys-SI-IR-02.1
Title	Simulation input data file format – ASCII header
Description	The ASCII header contains a single null-terminated string, coded in ASCII, with free text describing the contents of the log file.
Rationale	Since the remainder of the input data file is in binary format, the ASCII header is the only section that is directly readable by the user to identify the contents of the file.
Depends on:	
Decomposed by:	

Identifier	Sys-SI-IR-02.2
Title	Simulation input data file format – AoA configuration
Description	The AoA configuration field consists of the following elements: • number-of-streets-in-AoA (coded in 2 bytes) - Sys-SI-IR-01.2.1 • number-of-intersections-in-AoA (coded in 2 bytes - Sys-SI-IR-01.2.2 • list-of-street-configurations (coded in 8 bytes per list item) - Sys-SI-IR-01.2.3 • list-of-intersections (coded in 4 bytes per list item) - Sys-SI-IR-01.2.4 • list-of-blocks - Sys-SI-IR-01.2.5 • list-of-entry-points - Sys-SI-IR-01.2.6 • list-of-exit-points - Sys-SI-IR-01.2.6
Rationale	
Depends on:	
Decomposed by:	Sys-SI-IR-01.2.1, Sys-SI-IR-01.2.2, Sys-SI-IR-01.2.3, Sys-SI-IR-01.2.4, Sys-SI-IR-01.2.5, Sys-SI-IR-01.2.6

Identifier	Sys-SI-IR-02.3
Title	Simulation input data file format – initial state
Description	The initial state field consists of the following: • vector with the state of each semaphore. The index of the vector is the semaphore identifier (same identifier as the corresponding intersection) and each vector element is the state of that semaphore represented by the time in seconds in the semaphore's cycle. • list of vehicles along the AoA blocks. List format defined in Sys-SI-IR-01.3
Rationale	This information is sufficient to specify the exact time in each semaphore's cycle and the initial location of each vehicle that is already in the AoA at the start of the simulation. The specified vehicles may be in an entry buffer, exit buffer, moving in a specified block or stopped at a specified intersection.
Depends on:	Sys-SI-IR-01.3
Decomposed by:	

Identifier	Sys-SI-IR-02.4
Title	Simulation log file format – List of Events
Description	The format of each entry (5 bytes) in the list of events is: • event identifier (1 byte) – current-time (0), vehicle-p1-in-entry-buffer-p2 (3) • parameter 1 (2 bytes) – time (seconds field) or vehicle identifier. • parameter 2 (2 bytes) – time (milliseconds field) or buffer identifier. Remark: There is no explicit field stating the number of entries in the list of events, the list ends when the log file ends.
Rationale	
Depends on:	
Decomposed by:	

1.5 Simulation-Log Player

Identifier	Sys-PL-FR-01
Title	Simulation-Log Player Functionality
Description	The simulation log player presents to the user a graphical view of a previous simulation run. The simulation play-back can be executed either: • In continuous play-back mode with a speed selectable by the user, or • In step-by-step mode using the step-forward or step-backwards buttons.
Rationale	
Depends on:	
Decomposed by:	

Identifier	Sys-PL-FR-02
Title	Simulation-Log Player User Interface elements
Description	The user interface of the simulation log player includes the following controls: • Open file button to select the simulation-log file to be visualized • Step-forward and step-backwards buttons, • Continuous play and stop buttons, • Continuous play speed slider, • Current time slider, • Zoom slider, • Vertical and horizontal scroll.
Rationale	This set of controls allows the user to select a simulation-log file, execute its play-back in continuous mode at a selectable speed, stop the play-back at any point in time, play-back the simulation step-by-step either forward or backwards, and zoom into a specific area inside the AoA for better visualization.
Depends on:	
Decomposed by:	

Identifier	Sys-PL-FR-03
Title	Simulation-Log Player visualization area
Description	The simulation log player presents to the user a graphical view of a previous simulation run in a visualization area with the following graphical elements: • Streets – presented as two parallel lines with varying spacing and line width to represent streets with different number of lanes. • Vehicles – represented by squares of 10 different colors

	placed along the blocks of the streets. Vehicles currently in input or output buffers are not represented. • Input and output buffers – have a numeric indication of the number of vehicles currently inside each buffer. • Traffic Lights – represented by a square that is located in the center of each intersection. Two sides of the square have circles whose colors change among red, green, yellow representing the current state of each traffic light • Clock – presenting the current simulated real time.
Rationale	
Depends on:	
Decomposed by:	