Experience from a Modelling & Simulation Perspective in Smart Transport Information Service Design

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Paper presented by

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IESS 1.6 - 7th International Conference on Exploring Services Science

Content

- Research, application and development context
- Main results – *Socio-Technical Systems Engineering* (STSE) process
- Application example - real time information and travel planning service
- Conclusions

Research context

- the service sector accounts now for over 70% of the activities and employment in the more advanced economies, and has been growing in all countries
- innovation in services is critical for sustainable societies
- information technologies offer increasing support in providing new services
- new business models introduced by service organizations
  - service customer's experience is supposed to be embedded in the new service offerings and enterprise design
  - support: social computing, social software
- members of society interact with the service organizations, make informed (*smart*) decisions, work, and access new service offerings

- how to organize service systems activities in order to *customize service offerings based on the customers requirements*
  - new approach(es)

Application context

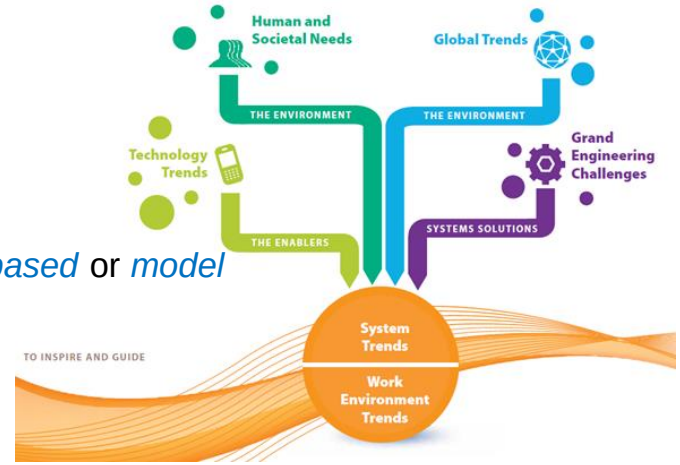
- Service systems engineering (SSE)
  - (BKCASE def.): … a multidisciplinary approach to manage and design value co-creation of a service system
    - it extends the holistic view of a system to a customer-centric, end-to-end view of service system design
  - Service systems engineer - has an *integrator* role, by considering the interface requirements for the interoperability of service system entities, for *technical integration*, and for the *processes* and *organization* required for *optimal customer experience* during service operations
    - SEBoK v. 1.5.1 released 18 December 2015 - BKCASE, Body of Knowledge and Curriculum to Advance Systems Engineering,, http://www.bkcase.org/
    - http://sebokwiki.org/wiki/Service_Systems_Engineering
  - this is a specific development approach
    - systematically and quantifiable *design*, *development*, *operation*, and *maintenance* of service systems

Application context

- Service systems engineering (SSE)
  - Why SSE is different?
    - emphasis on people and human behaviour
    - focus on Engineering rather than on Business, i.e. design, operations & problem solving
    - emphasis on process over product; not tied to manufacturing or mechanical engineering legacy
    - focus on customer interaction with service processes and systems

… *Knowledge is social, it is in communities where people enter in dialog* …

Development context



- INCOSE systems engineering vision for 2025:
  - the evolution of the systems engineering endeavours in a *model-based* or *model driven* context
  - application domain: service systems engineering
- **MBSE**: *Model-Based Systems Engineering*
  - a Systems Engineering paradigm - application of rigorous visual modelling principles and best practices to Systems Engineering activities throughout the System Development Life Cycle (SDLC), requirements analysis, validation and verification; system architecture specification, …
  - traditional *document-based* and *code-centric* processes -> *requirements-driven and architecture-centric* processes
- **M&SBSE**: *Modelling and Simulation-Based Systems Engineering*
  - supports an effective systems engineering process in which the model is still central, but it reinforces that this model should be executable
  - an M&SBSE process centralises experiences and successful best practices in the systems engineering endeavour, but …
  - it should integrate also design options to *validate design using an executable representation of requirements*

Main results

- Socio-technical description in service systems
  - actual service systems can be described as complex socio-technical systems, integrating business functions, technology and human resources, whose aim is the creation of value and benefit through the generated services

  - Monica Drăgoicea, João Falcão e Cunha, M. Pătraşcu: *Self-organising socio-technical description in service systems for supporting smart user decisions in public transport*. Expert Systems with Applications, 42(17-18), 6329-6341 (2015)

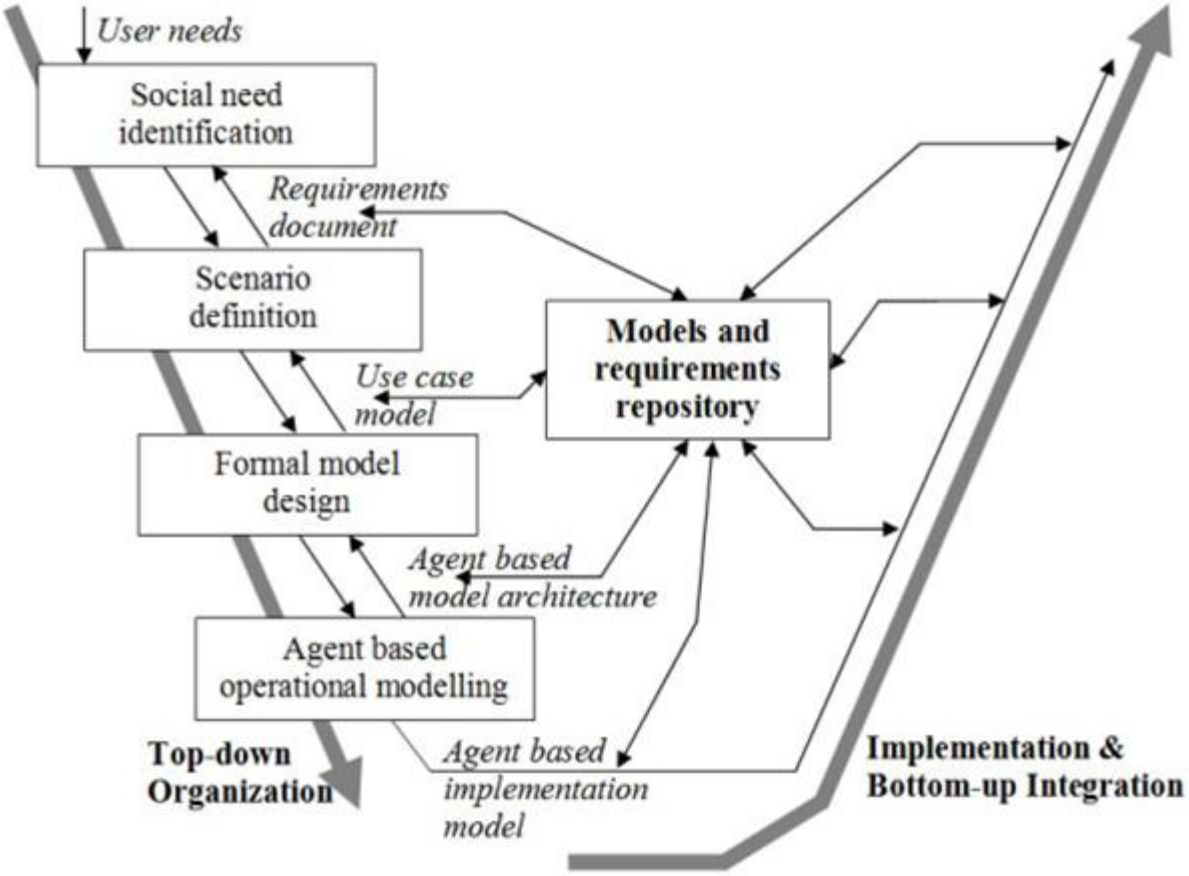
- Highlights
  - Exploration to transpose service science principles to guide service systems design
  - Modelling of value co-creation service interactions embedding customer experience
  - Description of the Socio-Technical Systems Engineering (STSE) process
  - Exploratory case study of a real time information and travel planning service
  - Integration guidelines of the STSE process steps with Presage2 multi-agent platform

Main application driver – agent technology

- **Agent Directed Simulation** initiative describes different forms of agent-related research, expressing:
  - agent simulation - the use of simulation for agents
  - agent supported-simulation, and agent-based simulation - the use of agents for simulation

- *agent-based system modelling and simulation*
  - relates to understanding system response, predicting behaviour and defining emergent behaviours
  - it uses orchestration, composition, and coordination of agent-based soft-wired components

STSE: Socio-Technical Systems Engineering process



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STSE: Socio-Technical Systems Engineering process

Table 1. The STSE process and the V-model for a systems engineering process

	Step 1	Step 2	Step 3	Step 4
STSE: Socio-technical systems engineering process	Social need identification	Scenario definition	Formal model design	Agent based operational modelling
Output:	Requirements document	Use case model	Agent based architectural model	Agent based implementation model (executable)
V-model for a systems engineering process	Concept of Operations	System Specification	High level design	Detailed design
Output:	Requirements document	System requirements document and use case model	Architectural analysis model	Software implementation model (executable)

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STSE: Socio-Technical Systems Engineering process

- **Step 1**. Social needs identification. The stakeholders' needs are identified, and value co-creation interactions are defined;
  - a *requirements document* is created to define overall system functionalities and performance criteria for system validation if a new service process development is motivated
- **Step 2**. Scenario definition. Value propositions are defined and a use case model is created to comply with the user identified needs;
  - definition of the agent based simulation scenarios, that will allow to validate different aspects of social interaction between the service consumer and the service provider; the output of this stage is the *use case model*
- **Step 3**. Formal model design. The output of this stage is the *proposed architecture of the agent based model*, consisting of:
  - a set of agents, the environment in which they operate, agent communication protocol, and the set of general rules according to which they execute their actions and access resources
- **Step 4.** Agent based operational modelling. The functional requirements are transformed into a coherent description of the service functionalities through *model execution*
  - a value-proposition-based interactions phase, in which the customer and provider may *negotiate in terms of value propositions*; investigates: a) the level of service quality promised by the provider against the needs of the customer, and b) the cost of the service utilization against the requested price that the customer has to pay.

Application – modelling example

- integration of agent-based modelling and simulation experience into the development of *smart transport information services*
- emphasises the role of the development platform that provides tools for *model analysis*, *validation*, *simulation*, and *real-time animation*
- the developed models can be defined consistently with user needs

Rational Rhapsody	*Modelling and design activities with Rhapsody*	*STSE Process*
analysis model perspective	requirements modelling	Step 1
	use case modelling	Step 2
	agents' interaction modelling	Step 3
state model perspective	state diagram modelling	Step 3
object model perspective	modelare diagrame de pachete	Step 4
	modelare diagrame de clase	Step 4
implementation model perspective	Java/Ada/C++/etc. code	Step 4
animation perspective	animated sequence diagrams (simulation)	verification and testing
	animated state diagrams (simulation)	

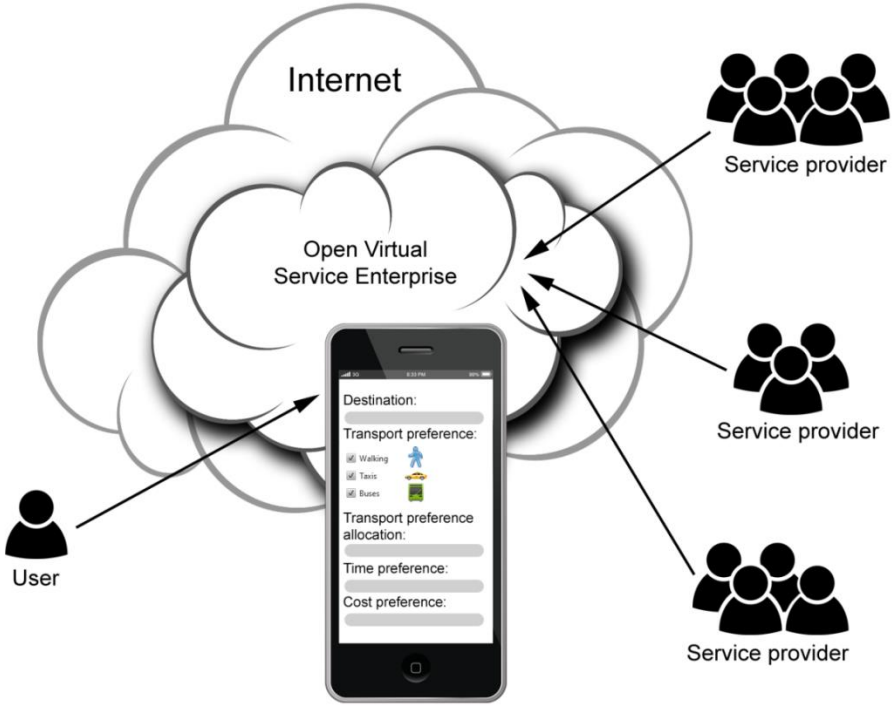
Table 2. Mapping of analysis, modelling and implementation activities from the STSE process with Rational Rhapsody

Application – modelling example

- double perspective of service provider and service customer for smart transport service development
- working scenario for a city transport information service to support travellers with valuable information regarding planning a trip in a city
  - smart decisions - evaluation of new public transport routes availability, extension of available routes, improvement of working shifts, acquisition of supplementary vehicles and improvement of existing business plans
  - interaction with registered service customers: service providers may gather information about utilization degrees of travel routes in the city, utilization degrees of transport vehicles, evaluation of peak hours, or seasonal trends

Application – usability

- Transport information service in the open virtual service enterprise environment
- Service customer perspective
  - an user (tourist) uses a smartphone mobile service application in order to plan his trip in a new city. He intends to access current information through the mobile device, trying to make smart decisions on daily travelling while interacting on-line with different transport service providers, taking into consideration personal preferences (budget, as time and money)
- Service provider perspective
  - Through his mobile device, a service customer can access the mobile information service available in an *open virtual service enterprise environment* to which several service providers can adhere. Service providers may formulate smart decisions that involves new value propositions



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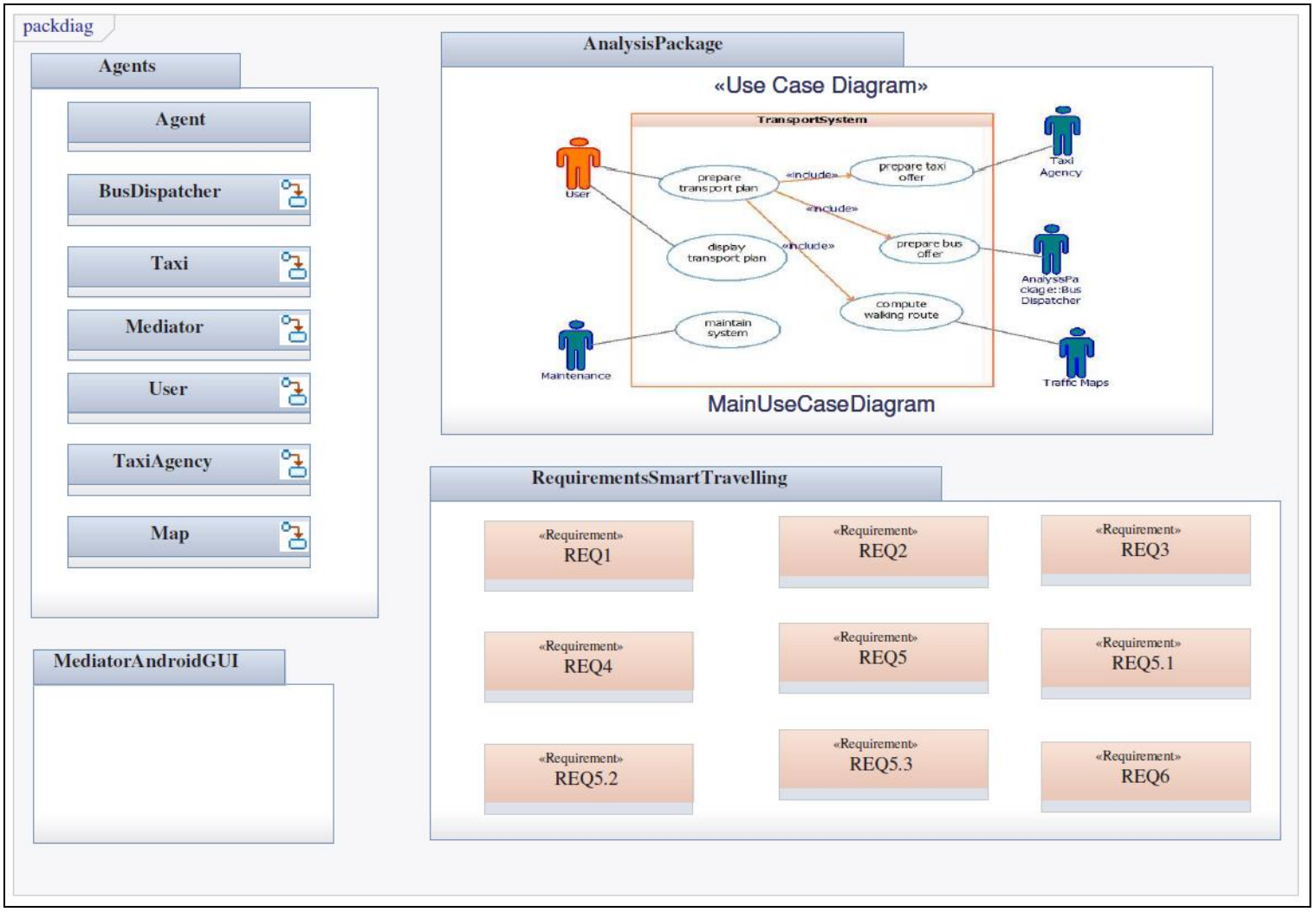
Application – modelling example



Package diagram (Rational Rhapsody) - components of the design and analysis model

Requirements Modelling in *Step 1* of the STSE Process

- **REQ1**. The information service should be able to generate possible routes for three modes of transport in a city, bus, taxi, and walking. Therefore, the software application has several interactions with bus and taxi dispatchers. It has to compute the walking route through interactions with a map application;
- **REQ2**. The software application allows to generate a list of transport offers according to the user's preferences and restrictions (destination, time, cost, transport modes);
- **REQ3**. Transport offers will be listed orderly according to the user's preferences. They will be prioritized according to the price of the trip (p) and the duration of the trip (d);
- **REQ4**. The user may opt to choose one travel route or to cancel the service;
- **REQ5**. Each generated transport offer has to include a description containing the transport mode, duration and cost. The following *service interactions* are defined:
  - **REQ5.1**. When a trip by taxi is chosen, the software application solicits the corresponding taxi dispatcher, then informs the taxi service user (taxi ID number and estimated time of arrival);
  - **REQ5.2.** When a trip by bus is chosen, the software application displays the route to the closest bus station, bus number, destination station name, and the path from the station to the destination. A detailed list of steps is generated if a bus exchange is needed;
  - **REQ5.3**. When walking is preferred for the trip, the software application will display a map showing the required path to follow;
- **REQ6.** The maintenance of the software application is supported by a technician.

Use Case Model in *Step 2* of the STSE Process

Step 2 (*Scenario definition*)

- definition of a use case model

Use case	Description	Actors	Type	Cross-Ref
Prepare transport plan	User agent request transport. Mediator agent interacts with Taxi Dispatcher, Bus Dispatcher, and Traffic Maps agents to prepare travel offer with user preferences. This use case includes Prepare taxi offer, Prepare bus offer, and Compute walking route use cases.	User	main	REQ1 REQ2
Display transport plan	Transport application returns to the user transport choices or details about transport mode. According to user choice, Mediator sends to user instructions to reach the destination (taxi - taxi ID, estimated arrival time); bus - route to the closest bus station, bus number, destination station name, path to final destination; walking - route to destination on map).	User	main	REQ1 REQ2 REQ4 REQ5 REQ5.1 REQ5.2 REQ5.2 REQ5.3
Prepare taxi offer	Transport application interacts with Taxi Agencies to prepare taxi transport offers, and to plan taxi trips on user request.	Taxi Agency	secondary	REQ5.1
Prepare bus offer	Transport application interacts with Bus Dispatcher agents to prepare bus transport offers.	Bus Dispatcher	secondary	REQ5.2
Compute walking route	Mediator interacts with maps application to prepare walking routes on user request.	Traffic Maps	secondary	REQ5.3
Maintain system	Technician performs maintenance operations on system.	Maintenance	secondary	REQ6

Agents' Interaction Model in *Step 3* of the STSE Process

Step 3 (*Formal model design*)

- proposed architecture of the agent based model

Use case diagram elements	Agent Type	Aim	Interacts with
User	**User**	Request transport with personal preferences	Mediator Taxi Bus
TransportSystem	**Mediator**	Mediates interactions between users and other actors	User Bus dispatcher Taxi Dispatcher Maps
Bus dispatcher	**Bus Dispatcher**	Coordinates Bus Dispatcher agents activity	Mediator Bus
Taxi Agency	**Taxi Dispather**	Coordinates Taxi Dispatcher agents activity	Mediator Taxi
–	**Taxi**	Transport by taxi	Taxi Dispatcher User
–	**Bus**	Transport by bus	Bus dispatcher User
Maintenance	**Maintenance**	Software application maintenance	Mediator
TrafficMaps	**Maps**	Traffic information (walking route maps)	Mediator

Agents' Interaction Model in *Step 3* of the STSE Process

Step 3 (*Formal model design*)

- proposed architecture of the agent based model

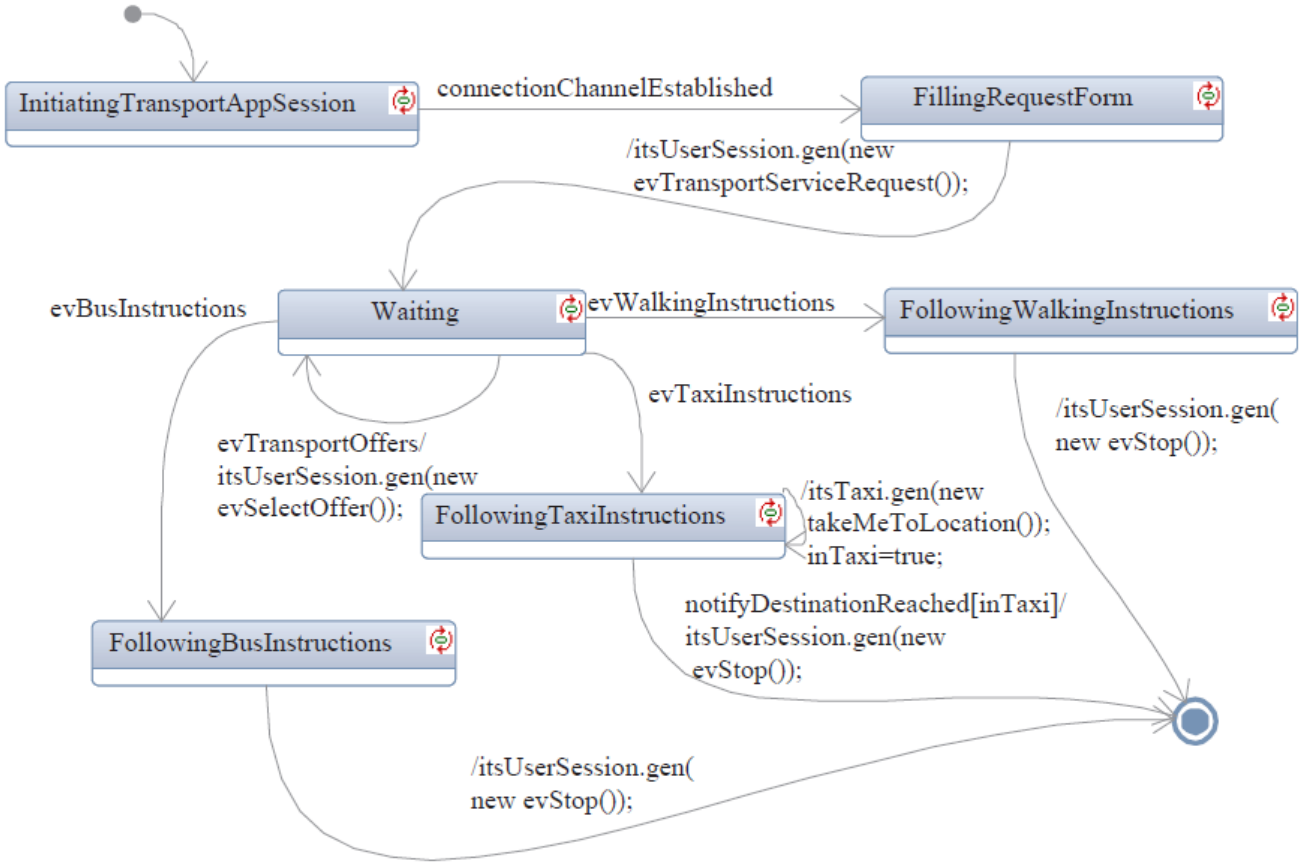


Fig. 2. State diagram - *User* agent

Agents' Interaction Model in *Step 3* of the STSE Process

Step 3 (*Formal model design*)

- proposed architecture of the agent based model

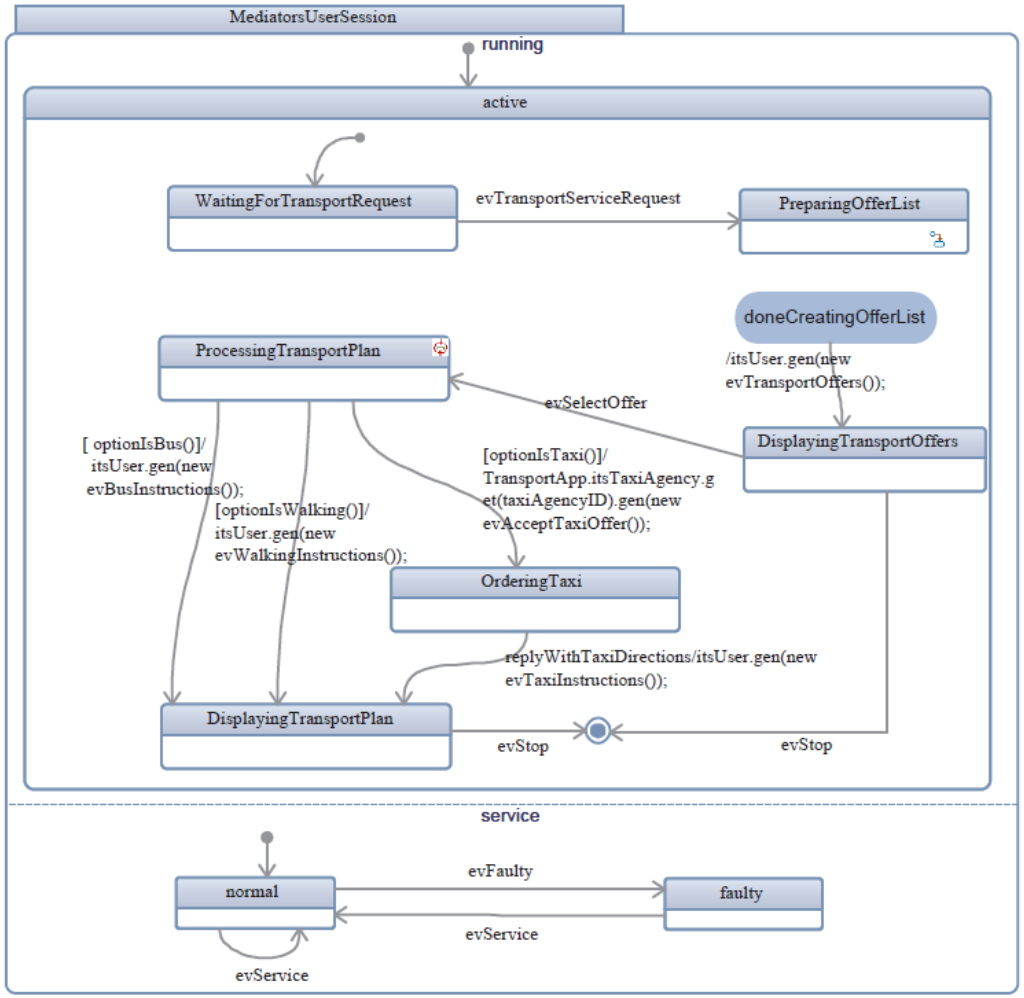


Fig. 3. State diagram - *Mediator* agent

Agents' Interaction Model in *Step 3* of the STSE Process

Step 3 (*Formal model design*)

- proposed architecture of the agent based model

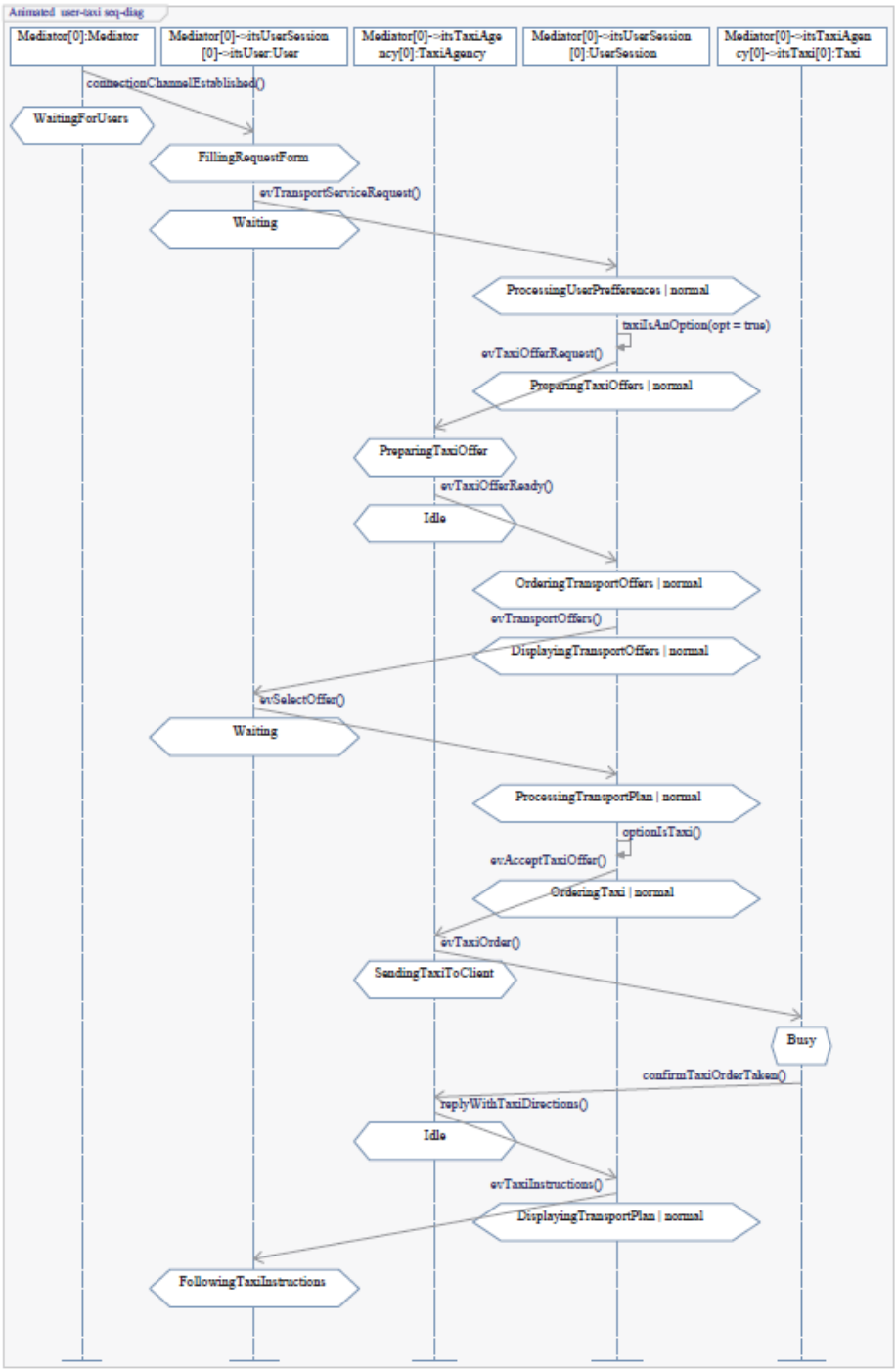
Agent	State	Next state	Trigger	Actions
User	InitiatigTransportSession	FillingRequestForm	connectionChannelEstablished	
	FillingTransportForm	Waiting	-	-evTransportServiceRequest
	Waiting	FollowingBusInstructions	evBusInstructions	-
	Waiting		evTaxiInstructions	-
	Waiting	FollowingTaxiInstructions	evWalkingInstructions	-
	Waiting	FollowingWalkingInstructions	evTransportOffers	evSelectOffer
	FollowingWalkingInstructions	Waiting	-	evStop
	FollowingBusInstructions	FIN	-	evStop
	FollowingTaxiInstructions	FIN	-	takeMeToLocation
	FollowingTaxiInstructions	FollowingTaxiInstructions	-	evStop
		FIN		
Taxi Agency	Idle	Idle	notifyTaskCompleted	-
		PreparingTaxiOffer	evTaxiOfferRequest evAcceptTaxiOffer	-
		SendigTaxiToClient	-	evTaxiOrder
	PreparingTaxiOffer	Idle	confirmTaxiOrderTaken	evTaxiOrderReady
	SendingTaxiToClient	Idle		replyWithtaxiDirections
Bus Dispatcher	Idle	PreparingtransportPlan	evBusOfferRequest	-
	PreparingTransportPlan	Idle	-	evBusOfferReady
Mediator	WaitingForUsers	SettingUpNewUserSession	requestUserConnection	-
	SettingUpNewUserSession	WaitingForUsers	-	-
	running :	active	-	-
	WaitingForTransportRequest	PreparingOfferList	-	-
	PreparingOfferList:	ProcessingUserPrefferences	-	-
	ProcessingUserPrefferences	PreparingTaxiOffers	-	evTaxiOfferRequest
		PreparingWalkingOffer	-	evWalkingOfferRequest
		PreparingBusOffer	-	-
	PreparingTaxiOffers	SortingTransportOffers	evTaxiOfferReady	-
	PreparingWalkingOffer	SortingTransportOffers	evWalkingOfferReady	-
	PreparingBusOffer	SortingTransportOffers	evBusOfferReady	-
	SortingTransportOffers	DisplayingTransportOffers	-	evTransportOffers
	DisplayingTransortOffers	ProcessingTransportPlan	evSelectOffer	-
		FIN	evStop	-
	ProcessingTransportPlan	DisplayingTransportPlan	evBusInstructions	-
		DisplayingTransportPlan	evWalkingInstructions	-
		OrderingTaxi	-	evAcceptTaxiOrder
	OrderingTaxi	DisplayingTransportPlan	replyWithTaxiDirections	evTaxiInstructions
	DisplayingTransportPlan	FIN	evStop	-
	normal	fauly	evFaulty	-
		normal	evService	-
	faulty	normal	evService	-
Taxi	WaitingForOrder	Busy	evTaxiOrder	confirmTaxiOrderTaken
	Busy	WaitingForOrder	-	notiFyDestinationReached
		Busy	takeMeToLocation	destACK=true;
Traffic Maps	Idle	PrepareWalkinOffer	evWalkingRequest	-
		ComputingRoute	confirmWalkigRequest	-
	PreparingWalkingOffer	Idle	-	evWalkingOfferReady
	ComputingRoute	Idle	replyWithWalkingDirections	-

Table 5. Agent interaction protocol for allocation of transport resources

Value-proposition-based Interaction Evaluation in *Step 4* of the STSE process

Step 4 (*Agent based operational modelling*)

- Animated sequence diagram - Taxi request interaction



Conclusions

- we explored the possibility to transpose service science principles to guide improved service design
- we approached a M&SBSE perspective in order to model value co-creation service interactions embedding customer experience
- we defined and applied a specific system engineering process - *Socio-Technical Systems Engineering* (STSE) – specifically tailored for service systems engineering
- we created and exploratory case study of a real time information and travel planning service
- we presented integration guidelines of the STSE process steps with:
  - Presage2, a simulation platform for rapid prototyping of Agent Societies, and with
  - Rational Rhapsody development platform, for embedded, real time or technical application software development based on the UML and SysML modelling standards, offering support for high-level modelling, and model execution through simulation and real-time animation

Conclusions

- we discussed the possibility of integrating agent-based modelling and simulation experience into the development of improved services
- we suggested that we can formalize service design activities towards the integration of customer experience, validated through service interaction modelling
- on our specific case study, we created an agent based executable model which seems suitable for:
  - obtaining *qualitative simulation* results, and
  - performing *quantitative evaluations* on operational aspects in transport service delivery

Thank you !