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A Capability – Driven modelling approach applied in smart transportation & management systems for large scale events

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Abstract

Economic growth in Europe has been, strongly associated with urbanization, overwhelming cities with vehicles. This renders mobility inside cities problematic, since it is often associated with large waste of time in traffic congestions, environmental pollution and accidents. Cities struggle to invent and deploy "smart" solutions in the domain of urban mobility, so as to offer innovative services to citizens and visitors and improve the overall quality of life. At the same time, organisation of large-scale events impose even more challenges and difficulties in the provision of such services. In this context, the paper discusses on the basic challenges that cities face especially in cases of large scale events, and proposes a capability – driven enterprise modelling approach towards enabling Smart Objects for Smart City Operations (SCO). It presents specific examples of deploying this approach in smart traffic management and smart spectators' management in large scale events. Moreover, a process towards linking capability models to simulation ones is presented, trying to set the basis for effective SCO based on Smart Objects deployment.

Keywords: smart cities, smart city operations, mobility, capability-driven approach, enterprise modelling.

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1. Introduction

During the last decade, there has been a significant increase in the amounts of uncorrelated and non-synchronized data that citizens may receive from innumerable sources and through various devices. Therefore, it is really challenging for them to efficiently handle this data; the difficulties they face result in relevant difficulties related to their mobility. For instance, no thorough door-to-door services / solutions are available, especially when dealing with multimodal transportation; moreover, it is really difficult to provide real-time and at the same time individualized services. The overall result for citizens comprises significant losses of time, decrease in the level of safety in mobility, pollution, degradation of life quality, and huge waste of non-renewable fossil energy. Also, not only the citizens are affected, but also a number of related stakeholders, including public authorities and enterprises.

On the other hand, smart cities are being developed nowadays all over the world, trying to offer traditional services with unconventional methods (e.g. via Information and Communication Technologies – ICT), as well as completely novel services, often enabled again by ICT [1] [2].

Urban mobility constitutes an area where SCOs find prosperous ground. This is justified from the fact that the demand for urban mobility is ever increasing, especially in large cities, incurring several unpleasant everyday phenomena, such as traffic jams, environmental pollution, accidents and an overall degradation of the life quality. At the same time novel urban mobility schemes, business models and services arise at a high pace, such as ridesharing car sharing, e-ticketing methods for mass public transport, etc. Those services are usually developed by private entities, whilst it also lies among a (large) city's fundamental priorities to improve current mobility practices and provide intelligent services to their citizens and visitors [3].

In this respect, it would be interesting to work on improving current and employ novel urban mobility practices, whilst, concurrently developing novel SCOs for citizens and visitors of a "Smart City (SC)". Although there is not yet a formal and widely accepted definition of "Smart City," the final aim is to make a better use of the public resources, increasing the quality of the services offered to the citizens, while reducing the operational costs of the public administrations. This requires engineering methods for the aggregation, classification, processing and exploitation of large amounts of uncorrelated data, extracted from versatile sources. The above processes can only be carried out effectively through Smart Objects and IoT (Internet of Things). Smart Objects involve sensors and actuators for sensing the environment and aggregating data that could be of use for an SCO. At the same time, the application of IoT management and optimization strategies in an urban context responds to the strong push of many national governments to adopt ICT solutions in the management of public affairs, thus realizing the Smart City concept [13][14] . At the same time, it is attractive for local and regional administrations that may become the early adopters of such technologies, thus acting as catalysers for the adoption of the IoT paradigm at a wider scale.

This paper contributes to several of the aforementioned areas that are relevant to the application of IoT technologies to a Smart City:

a) Proposes a capability – driven enterprise modelling approach to address the main challenges related to smart city operations focusing specifically on large – scale events;

b) Proposes some methodological considerations for addressing the challenges;

c) Describing two use cases for describing the enterprise modelling approach in practice, dealing with traffic management and spectators management in large – scale events.

The paper is structured as follows. Section 2 presents and analyzes the capability – driven enterprise modelling approach, while section 3 presents the implementation of this approach in practice, using two examples: one related to smart transportation management and another focusing on smart management of spectators in large scale events. Section 4 describes a method to link capability models to simulation models. Concluding remarks and some perspective future work areas are drawn in section 5.

2. A Capability Driven Approach

The notion of 'capability' can be found in *strategic management* where one can distinguish between two prevailing views namely those of the Resource Based View (RBV) [21][22]and the Dynamic Capability View (DCV) [21]. In the field of *Information Systems* modelling enterprise capabilities has been proposed by both academia [23][24] and practice [25] as the lynchpin to connecting strategic objectives and high level organizational requirements to technological artifacts. From a service orientation perspective a business capability is defined in [26] as: "A particular ability or capacity that a business may possess or exchange to achieve a specific purpose or outcome. A capability describes what the business does (outcomes and service levels) that creates value for customers; for example, pay employee or ship product. A business capability abstracts and encapsulates the people, process/procedures, technology, and information into the essential building blocks needed to facilitate performance improvement and redesign analysis".

The Framework

We propose the adoption of an Enterprise Modeling approach in order to enable smart objects in SCO, based on the notion of 'capability' within a framework that considers 5 interrelated viewpoints as shown in Figure 1. This is based on a paradigm [27], which is partly influenced by previously developed schemes in Enterprise Modelling e.g. [28], and extended with new features that offers opportunities for a greater level of analysis [27]. Within this modelling framework, developers can follow a process that is depicted graphically in Figure 2.

(Step 1) define the enterprise situation in terms of the enterprise goals and the services that achieve these goals in a specific context; (step 2) identify required capabilities as a configuration of resources; (step 3) calculate the level of service based on capabilities; (step 4) reconfigure capabilities and (step 5) revise situation, if necessary.

Developing applications using these intertwined modelling viewpoints would be done through well-established conceptual modelling languages. For example, for business process modelling a modeller would use BPMN [24]), for goal modelling one of a number of candidates such as EKD [20, 25], or i* [26], business rules [18, 27, 28], actors and roles [29], strategic dependency [26] etc.

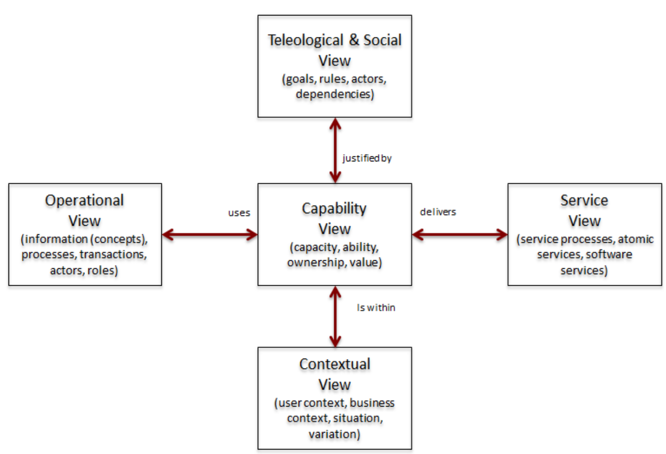


Figure 1: The five interrelated viewpoints for Capability driven design

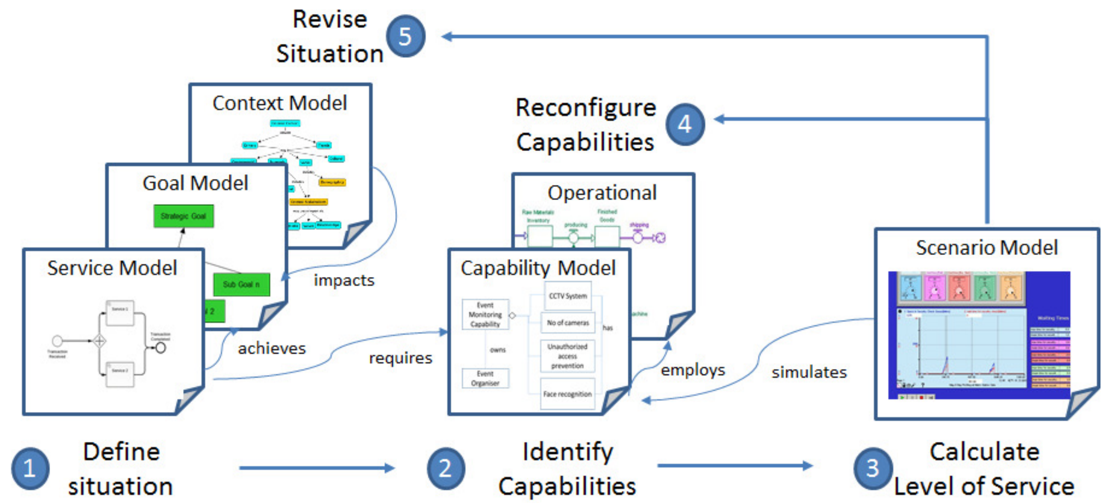


Figure 2: Process for modelling framework

Descriptive Components of 'Capability'

A discussion of each one of these different modelling viewpoints would, by necessity, require a long

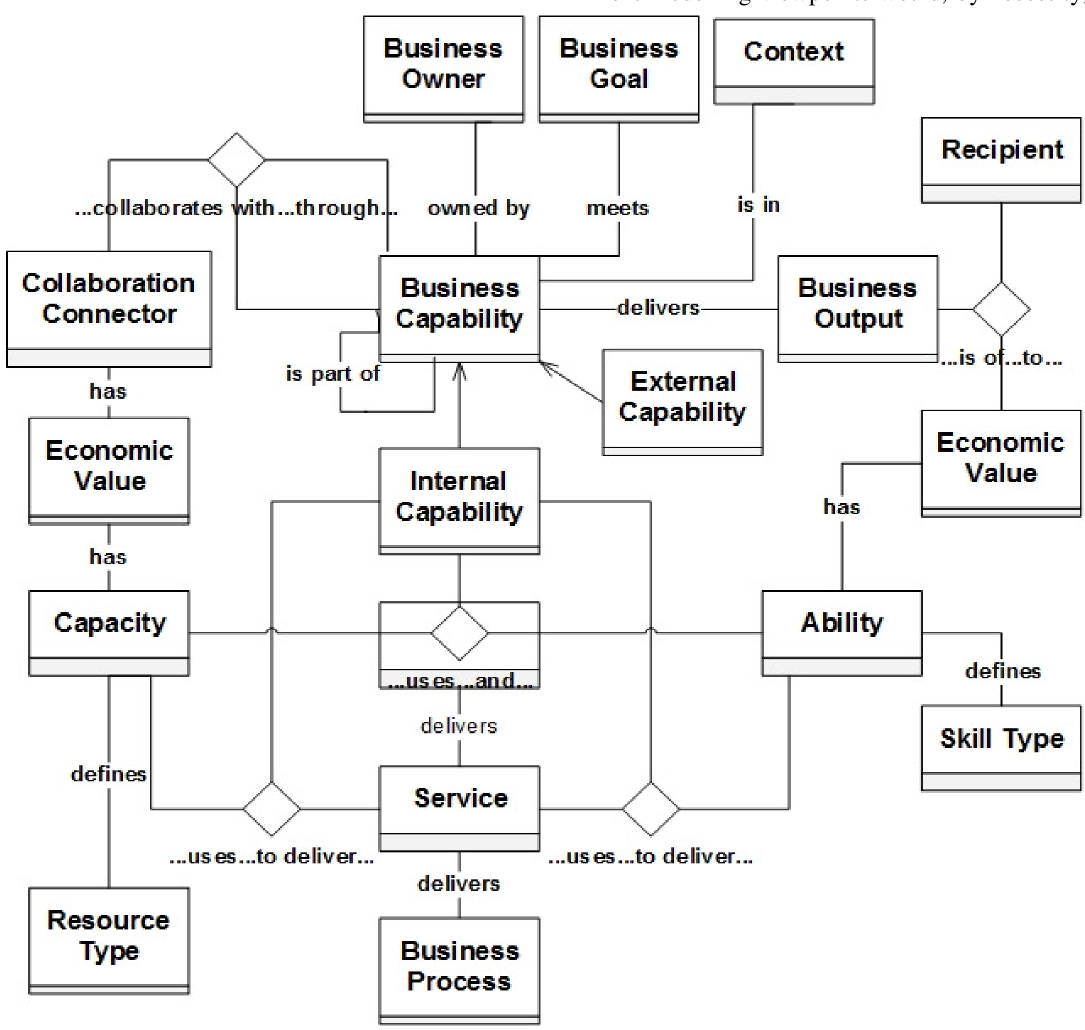


Figure 3: The capability meta-model

discussion that for pragmatic reasons is beyond the scope of this paper. It is important however, to delve deeper into the conceptual elements of ‘capability’, since these concepts will be referred to in subsequent sections dealing with the case study, and assume that the reader is familiar with modelling schemes of the other 4 viewpoints. Therefore, provides a top-level view of the capability meta-model.

A *business capability* is related to *business goals* and the *context* within which it exists. For example, the capability “Alerting mechanism” meets the goal “To alert when regulations are not met” in the context of “Local Port Authority Regulations; and Vessels Status”.

A *business capability* produces some *business output* received by some *recipient* and this may result in a financial transaction with an *economic value* associated with it. For example, the capability “Maritime Management” provides a service (output) “Chartering Services” to MariServe clients, i.e. ship owning companies (recipient) and this has a financial benefit to MariServe (economic value).

A *business capability* is associated with a specific *owner*. In both of the above examples, the owner of the two capabilities cited is MariServe themselves. However, in a particular business situation there may be a multitude of owners and this is particularly important in the era of collaborating enterprises to understand how a business service may be delivered through a collaboration of capabilities. For example, MariServe offers a variety of services to its clients, one such service being its “Web Conferencing” service. This is delivered through the MariServe capability “Social Networking”. But, in order to deliver this service MariServe needs to utilise two capabilities that are not owned by themselves, these being “Technical Assistance Management” owned by ComSys and “Web Conference Management” owned by Microsoft. This example highlights the need to cater for situations where capabilities, external to the enterprise being modelled, need to be identified. Therefore, in the meta-model a distinction is made between *internal capabilities* and *external capabilities*. Obviously, the details of external capabilities owned by some other enterprise, may not be important to know, or indeed as will probably be the most common case, may never be known, since such capabilities are considered as competitive advantage to the owner enterprise. What matters however, is that such an external capability is required in order to deliver a service and as such they should be part of the integrated enterprise capability model.

Collaborations with external capabilities (and indeed between internal capabilities, as can be seen in the meta-model) may exist; these should be modelled and analysed if one is engaged in a capability-driven development approach. The *collaboration connector* in the meta-model signifies these collaborations. Collaborations may be effected through shared *procedures*, exchange of *information* or common *policy* adoption. Collaboration, especially that comprising an external collaboration, will most probably involve a financial transaction so that an *economic value* should be considered.

A business capability may be composed of other sub-capabilities. Normally, such information will be available only for internal capabilities but in the meta-model, this *decomposition relation* is shown at the super-type level to include also external capabilities just in case such information is available. An example of this is the decomposition of the capability “Maritime Compliance” into 3 distinct sub-capabilities of “Regulation inconsistencies reporting”, “Port regulations monitoring” and “Vessel monitoring”.

Capacity and *ability* may be either external or internal. The economic value through a financial transaction would be different. For example, one might wish to utilise an external resource for which of course there will be a cost associated with it. On the other hand, some capacity or ability that is owned by MariServe may yield some profit to them. The economic value concept is necessary in these situations if one is interested in developing business models based on financial performance, either for existing situations or for projected ones.

The meta-model shows three fact types, “capacity-service”, “ability-service” and “capacity-ability-service”. All three may exist in their own right whether one considers the notion of capability or not. When however one considers modelling capabilities, then these three fact types may be considered as object types in their own right and each play a part in a different fact type namely “internal capability-<capacity, service>”, “internal capability-<ability, service>” and “internal capability-<capacity, ability, service>”.

Methodological Considerations

A general methodology strategy that may be followed using the notion of capability as a central tenet of Enterprise Modelling part is presented in the “method map” of Figure 4. This is akin to strategy maps [30] that defines four major stages: (a) the “as-is” stage, in order to define what is the current set if capabilities, (b) the “change” stage, in order to define the user requirements and analyse the needs for change, (c) the to-be” stage, in order to define the future capabilities and (d) the “evaluation” stage, in order to define the alternative options and the costs and benefits associated with each.

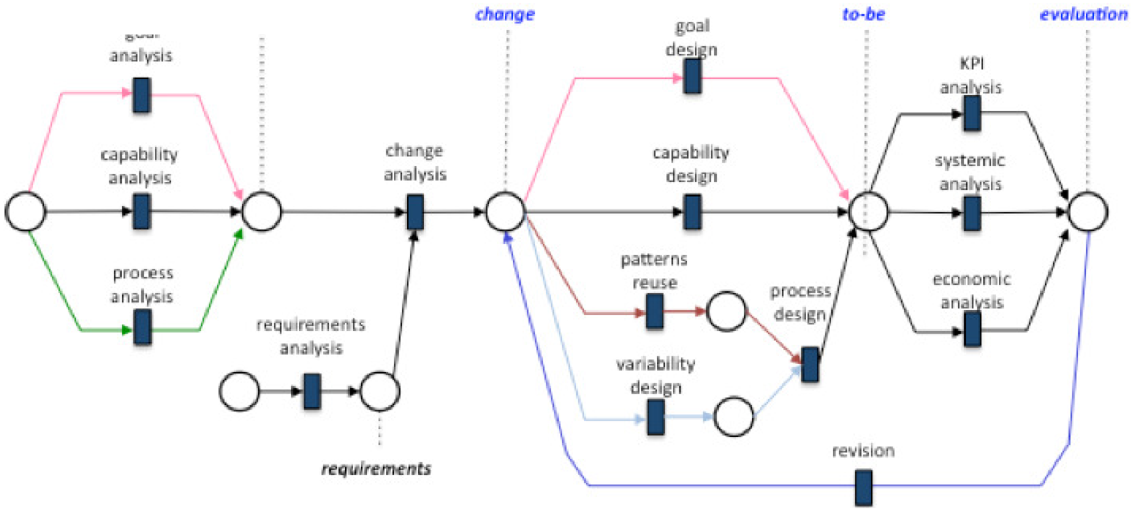


Figure 2: The overall process methodology

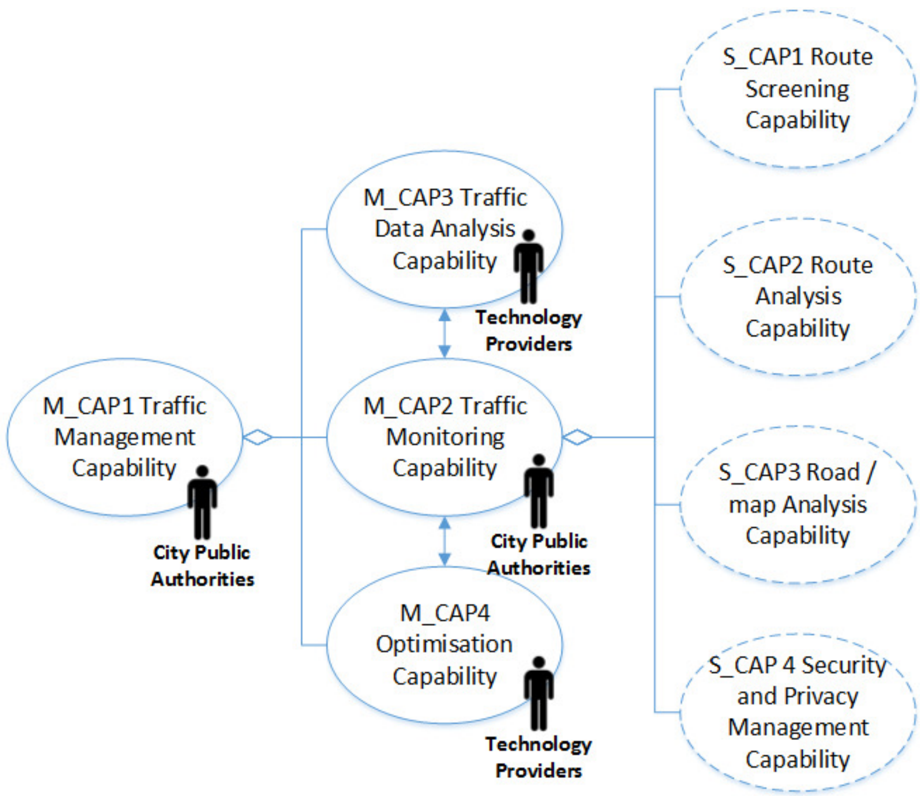


Figure 3 Main capability collaboration diagram

3. The Capability driven approach applications

Enterprise Capability Modelling in Practice: Traffic Management

Based on the aforementioned strategies and methodologies, we can proceed with a basic capability modelling example in practice. Focusing on a smart traffic management system, the capability analysis of an envisioned system is depicted in Figure 3. According to that, traffic management is comprised by three main other capabilities: traffic data analysis capability, traffic monitoring capability and optimisation capability. If we choose to focus on the traffic monitoring capability, we can find additional, secondary capabilities, such as the route screening capability, the route analysis capability, the road map analysis capability and the security and privacy management capability.

These capabilities are directly related to specific services, as shown in Table 1: for instance, the traffic management capability is delivered through the ‘real time directions’ service and the ‘traffic congestion minimisation’ service; the traffic monitoring capability through the real time data capturing service and the 100% city coverage service, etc.

Main Capabilities	Provided Services
M_CAP1 Traffic Management Capability	Real time directions
	Traffic congestion minimisation
M_CAP2 Traffic Monitoring Capability	Real time traffic data capturing
	100% city coverage
M_CAP3 Traffic Data Analysis Capability	Real time traffic data analysis
M_CAP4 Optimisation Capability	Route optimisation

Table 1: Services delivered by main capabilities

A similar analysis can be carried out with respect to the goals. A simple goal model is presented in Figure 6. Reducing traffic congestions may be the main goal; it is further analysed to the goal of traffic monitoring, routing optimisation and dealing with privacy and security issues. The traffic monitoring goal is achieved if the screening vehicles’ routes goal is achieved; similarly, the routing optimisation goal is achieved if the effective analysis of vehicles’ routing goal is achieved.

Following another approach, a strategic goal could be to ‘Smooth traffic in rush hours’, which is achieved by the ‘Traffic control service’ provided by the ‘Traffic control Smart objects Division’. The contextual parameters affecting the delivery of this service include the particular traffic / geographical characteristics, the type and number of expected cars in specific locations and the expected routes, etc. (Step 1). Provision of the ‘Traffic control service’ requires ‘Route screening capability’ which is based in smart objects around the city and in turn employs a number of screening stations, having certain throughput, i.e., number of cars crossing a specific point per time unit (Step 2). Analysing the ‘Route screening capability’ in the current context (referred to as scenario modeling) signifies the level of service that is achieved in terms of delay time per car (Step 3). Depending on the estimated level of service it might become necessary to reconfigure the ‘Route screening capability’ (e.g., increase number of screening stations and/or add ‘route management capability’) (Step 4) or even revise the situation (e.g., allocate / propose additional routes) (Step 5).

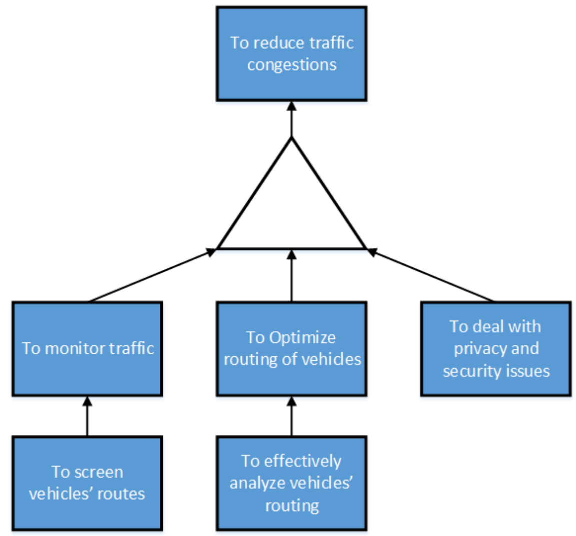
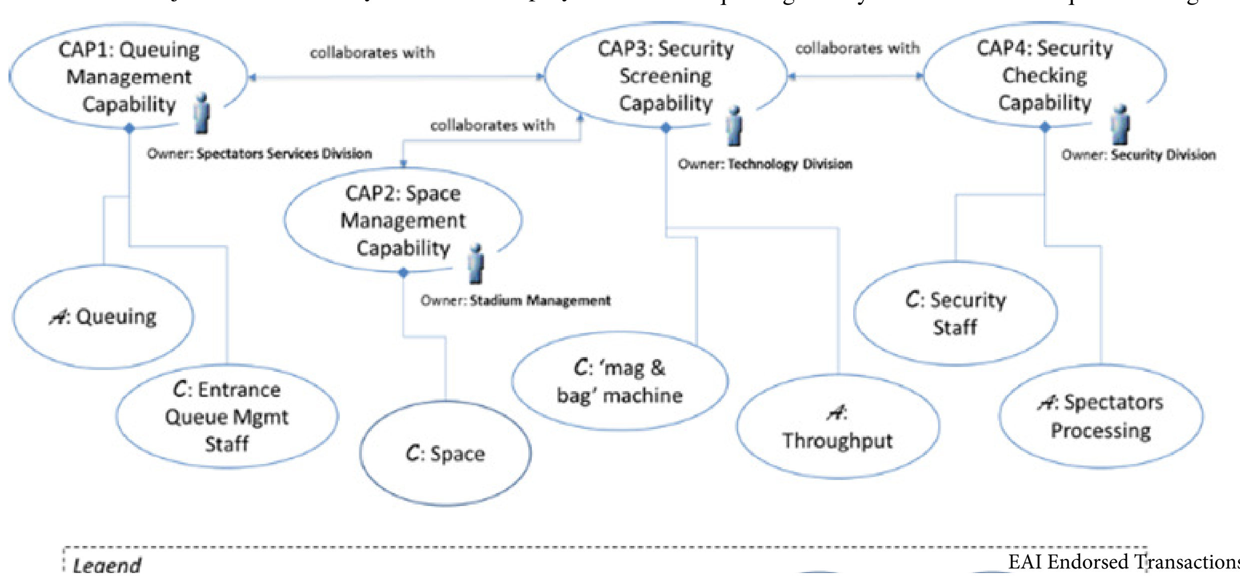


Figure 4: Goals Analysis

Enterprise Capability Modelling in Practice: Large scale events

A similar analysis has been made in regards to the organisation of large scale events, focusing on safety procedures for the spectators. Such a detailed analysis in regards to capabilities is presented in Figure 7, where each capability is analysed to its capacity and ability: for instance, the queuing management capability comprises the queuing ability and the entrance queue management



staff capacity; the security screening capability also collaborates with the space management capability and it is analyses to its throughput ability and the 'mag and bag' machines capacity, etc.

4. Linking Capability Models to Simulation Models

The simulation results comprise quantitative, time-based and cost-related information about process execution and resource usage, e.g. waiting times, throughput times, resource utilization. In output analysis, it can be interesting to evaluate the data at a certain point in time, e.g. the number of completed process instances at the end of the simulation time, or over time, e.g. the development of waiting times after a peak in demand. The specific type of data to be generated by simulation and how it is analysed depends on the analysis goal.

In the capability-driven approach, capabilities need to be expressed in terms of output analysis goals. As a capability enables an enterprise to provide a service in order to achieve a goal in a specific context, we need to investigate whether the triplet (goal, context, service) may be fulfilled. This means that all three attributes need to be expressed in simulation terms. To ensure validity, the description of both the level or service and the context needs to be very specific.

For this purpose, the following steps are proposed to ensure mapping of the (goal, context, service) triplet to the simulation environment.

1. Express context in terms of simulation parameters, decisions variables or other model aspects, e.g. in a specific Avenue there are 5 smart objects for car screening, mean car velocity is 15 Km/h, distribution is exponential.
2. Express level of service requirements in terms of specific simulation output parameters, e.g. level of service is the percentage of cars finding a route faster than the average
3. Express goals in terms of output analysis goals, e.g. percentage of cars finding a route faster than the average = 100%
4. Perform experimentation to determine if output analysis goals may be satisfied at the required level of service

To provide extensive design support through simulation, we also consider employing goal driven simulation. In goal driven simulation (GDS), we may automate many of the output analysis and experimental design tasks of a simulation study. This may include determining parameters to change, suggesting a rate of change, and testing these changes against a pre-established set of goals. To accomplish goal driven simulation, we need to integrate techniques such as object-oriented design, knowledge based systems and neural nets. In this case, there are still several issues to resolve including the type of interaction between these techniques and output analysis.

Goal driven simulation may be employed when goals are not met at the required level of service for a specific context, to indicate alternative contexts where goals may be met. In this case, we may then examine whether this context may be realistic in terms of design, cost etc. constraints.

To provide this capability, we add an extra step:

5. Experiment with different model parameters (decision variables) or the model itself to test various process and environment scenarios, to determine alternative contexts where goals may be met.

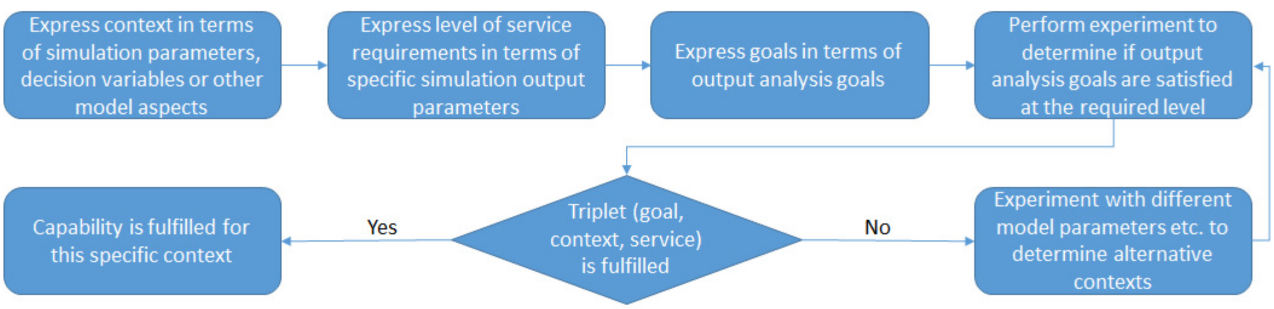


Figure 8: Steps towards capability fulfilment

Our overall proposed approach for linking capability models with simulation modelling and experimentation is presented in Figure 8.

5. Conclusions and Future Directions

This paper discussed on a capability – driven modelling approach, towards enabling Smart Objects and providing SCO, focusing on smart mobility services. As such, it first provided some basic challenges that cities face when designing SCOs. Then it focused on the role of Smart Objects for the implementation of such operations, and presented a detailed analysis of the capability – driven enterprise modeling approach, followed by a method to link capability models to simulation models.

Overall, smart cities are continuously getting smarter. This naturally requires capital expenditure and calls for novel solutions in various areas, especially regarding

Smart Objects and similar infrastructure. Transportation is an area where SCO find prosperous ground since it can increase the quality of living in large cities.

Several exciting areas are yet to be explored in the area of mobility offered in the context of SCOs. In particular, the further exploitation of intelligent transport systems principles in SCOs can lead to a 100% real-time assessment of traffic congestions, a priori identification of forthcoming dangers, as well as to the provision of open APIs and interfaces for intermodal MaaS inside cities/regions. Moreover, city-wide services can inform drivers on city-specific events (cultural, etc.), as well as on city-specific incidents (e.g. protests, works, etc.) and offer also targeted/focused ads and infotainment. Last, the exploitation of modern mobile communication infrastructures (e.g. 5G D2D) with which cities are more or less equipped, can naturally reduce deployment costs and provide low-latency emergency management services.

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