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D3.2: Experimental Methodology for Urban-Scale Media Trials

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The methodology presented here is to guide parties executing experiments and trials on the FLAME platform: both the validation experiments driving the evolution of the facility and those to be funded through open calls. The methodology sets out concerns of different stakeholders and how trials can lead to new knowledge and ultimately business value. Media service characteristics such as personalisation, interactivity, mobility and localisation and their relation to user privacy are explored as well as concepts such as quality of service and quality of experience. Techniques for conducting experiments at various scales and points through the development process are enumerated and an initial characterisation of the four validation experiments is provided.

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EXECUTIVE SUMMARY

FLAME is challenged to demonstrate convincing evidence that its platform can realise compelling user experiences and meet project value propositions through the innovative delivery of new digital media services. To meet this challenge, we set out a methodology that identifies the key stakeholders for whom benefits and impacts may be realised through the use of the FLAME platform. We describe how the knowledge generated through the execution of the FLAME methodology will lead to value creation for these individuals. The FLAME 'knowledge model' described in this document provides an over-arching structure for understanding the outcomes of experimental approaches taken in the project such that the value of the platform as a whole can be better understood. Our exploration of the methodology describes how to instantiate and then iteratively develop experimental evaluations of FLAME-based digital media services. We relate these methods to the expected operation of the FLAME platform architecture. Finally we review the up-coming vertical validation experimentation activities planned for later in the project and offer an indicative summary of each with respect to the methodology defined in this document.

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ABBREVIATIONS

OTT	Over The Top
PIML	Personalisation, Interactivity, Mobility and Localisation
QoE	Quality of Experience
QoS	Quality of Service
SDN	Software Defined Networking
SFC	Service Function Chain
SLA	Service Level Agreement

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1 INTRODUCTION

1.1 SCOPE AND AUDIENCE

This deliverable sets out the goals, methodology, evaluation framework and planned work of FLAME's first vertical validation experiments. In presenting this first version of the FLAME methodology, we present a knowledge model and process that serves to develop the project's understanding of the value and impact of the FLAME platform. Experimenters will refer to the FLAME methodology for guidance on how best to frame their experimental objectives and select from a range of methods. Indicative methodologies for the broadcast, gaming and transmedia vertical experiments are provided to illustrate the application of the FLAME methodology.

Readers of this document are assumed to include existing project partners and related stakeholders whom have at least an initial understanding of the project's aims and objectives. Their interest in this work will be motivated by their wish to better understand the key concepts to define FLAME value propositions and the methods by which evidence will be generated to support them.

1.2 FLAME INFORMATION MODEL

In this document we use a number of terms to describe activities, technical components and processes in a specific way. In the table below we provide definitions for the key terms used in this document.

Table 1: Summary of experiment, trial and test terms

Term	Definition
Experiment	An "experiment" is an evaluation of one or more FLAME platform components, deployed in a city and executed under repeatable, controlled conditions during which time any human behaviour related to platform usage is emulated using repeatable, machine based methods.
Trial	A "trial" is an evaluation of the use of FLAME media applications and services that use the FLAME platform under real-world conditions. Such an evaluation will be conducted with real users in a selected city environment using the FLAME platform operating using a repeatable configuration and deployment pattern.
Test	Experiments and trials are both sorts of tests. The word "test" is also applied to various software engineering techniques (e.g. unit test, integration test, etc) applied in the development of the FLAME platform and the development of media services. These software tests will be conducted on an integration platform before deployment in a city and do not form part of the methodology.

The information model shown in Figure 1 shows the links between various pieces of information being developed in the project. The methodology is designed to suit the types of scenarios FLAME is considering but is constrained both by the platform functions and, importantly, by the ethics

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requirements (e.g. data protection, equality, risk assessment). The methodology is used to help design the experiments and trials which test the scenarios (for more information on the project scenarios and media service use-cases, the reader is referred to FLAME deliverable D3.1 "FMI Vision, Use cases and Scenarios v1").

During the early phases of this project we must engage with stakeholders to understand their existing value networks and explore how FLAME can enhance or positively disrupt these. Later, as we generate knowledge based on compelling evidence, through experimentation and trial based methods, we will be able express that value in business terms that are predicated on improvements in efficiencies/costs only provided by FLAME.

The methodology also guides us in terms of what kinds of testing should be carried out in order to understand the demands likely to be made on the components that make up the platform. Finally, related to this, our methodology should provide a consistent process for all FLAME experimenters to follow. In doing this we will be in a strong position to effectively and coherently communicate the successes of the FLAME project to the world.

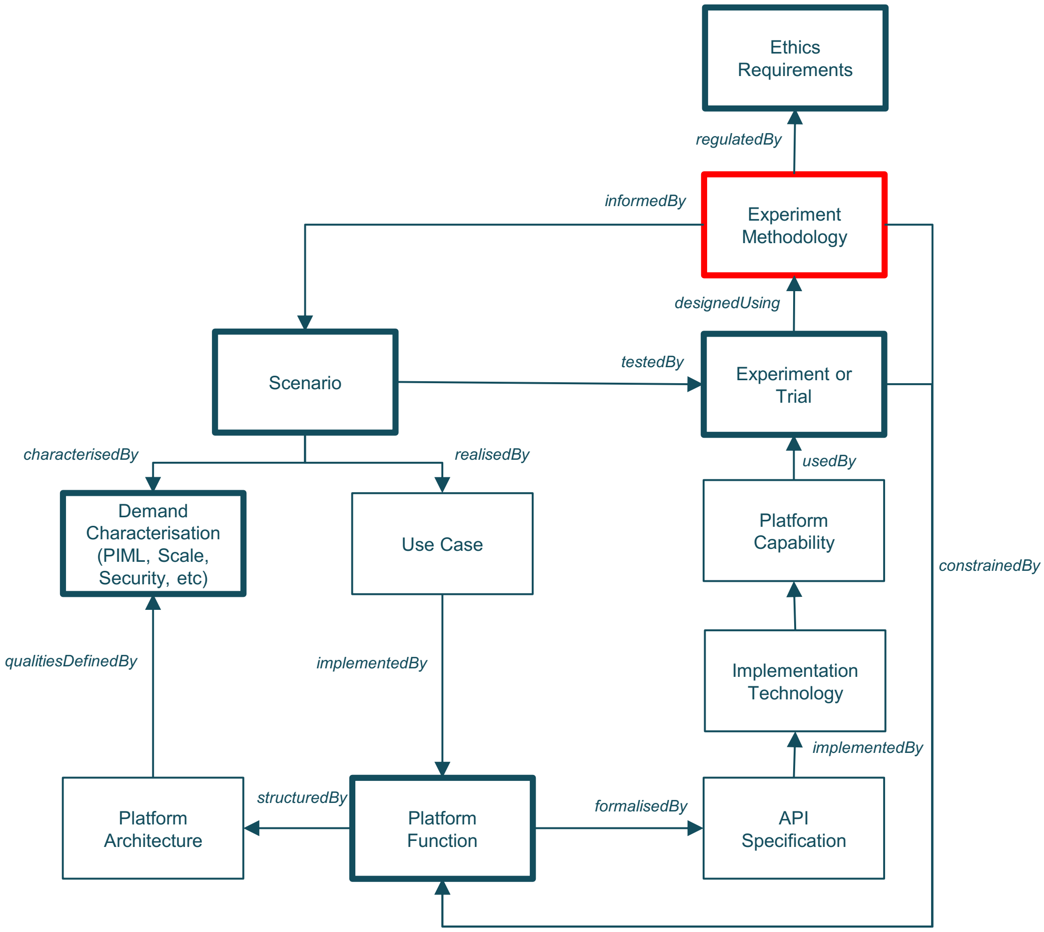

Figure 1. Schematic showing the main links between the methodology and related activities.

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1.3 RELATION TO OTHER FLAME ACTIVITIES

There are a number of important relationships between the methodology and other FLAME activities and documents which are outlined in Figure 2.

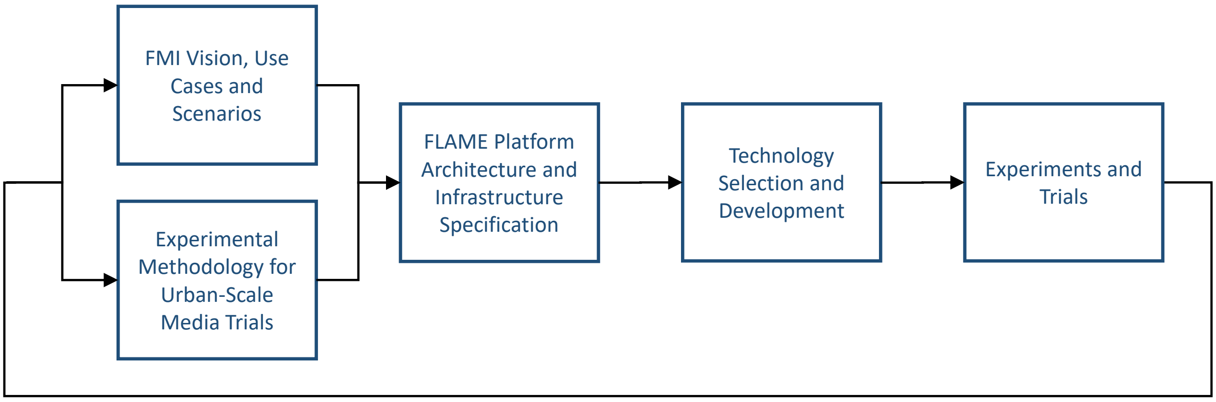

Figure 2. Overview of related FLAME activities.

- The methodology described here is informed by the scenarios which are being documented in parallel in FLAME deliverable D3.1 "FMI Vision, Use Cases and Scenarios v1" and made appropriate to the situations the FLAME project is considering. A preliminary indication of the experimentation related to these scenarios in terms of the methodology can be found in Section 3 of this document.

- The methodology is constrained and regulated by the ethics requirements documented in two confidential documents delivered at the same time as this document. Safety of participants and their data must be considered as well as issues of equality and non-discrimination.

- The methodology assists in defining the key PIML demand and usage characteristics which characterise the scenarios and drive and quantify the use cases of the platform architecture and functions to be documented in FLAME deliverable D3.3 "FLAME Platform Architecture and Infrastructure Specification v1".

The process is iterative: following technology selection and development and the first experimentation and trials, the FMI Vision and this document will both be updated and feed into an updated architecture and subsequent developments and trials.

1.4 OUTLINE

This document first presents the methodology in section 2 and then, in section 3 provides a first attempt at describing some aspects of the validating experiments (being developed in parallel) in terms drawn from the methodology.

In the methodology description we describe the rationale and goals (section 2.1), the stakeholders (section 2.2) and how the methodology drives value creation (section 2.3). The knowledge development process is described (section 2.4) and then we describe in detail the personalisation, interactivity, mobility and localisation (PIML) characteristics which are of key importance to driving

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technical features and driving value (section 2.5). The section concludes with descriptions of methods to be used at various stages of the process to generate the required knowledge (section 2.6).

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2 THE FLAME METHODOLOGY

2.1 METHODOLOGY RATIONALE AND GOALS

In this section we discuss the need for a methodology in FLAME, how it drives knowledge generation in the project, and what that potentially means in terms of creating benefits and impacts. We will look at what we want we intend to learn - this is encapsulated in what we call the FLAME knowledge model. In order to understand the utility and meaning of this knowledge, we will identify a range of stakeholders who have an interest in the platform and look at why this knowledge is important to them.

Why does the FLAME project need an experimental methodology? Ultimately we must be able to make compelling statements about the value of the FLAME platform in the real world. To do this, we must generate knowledge about the platform. What should this knowledge reflect? It should show how stakeholders representative of the vertical markets identified in this project benefit from the positive, disruptive changes to demand and delivery of media functions provided through the FLAME platform. In this project, we characterise demand in terms of *Personalisation*, *Interactivity*, *Mobility* and *Localisation* (PIML); the meaning of each of these terms is described further in section 2.5. As our understanding in this area develops, we will be able to encapsulate what we learn about the optimal delivery of PIML based experiences into policies and configurations for the FLAME platform that can lead to 'turn-key' deployments tailored to meet certain patterns of demand and use. In doing so, we have the potential to significantly reduce the effort that would otherwise be required to validate a new digital media services such that they are ready for market.

Our methodology will also provide a process and guidance to help maintain the quality and consistency of experiments and trials. It is important in FLAME that the methods used to evaluate the platform sit within a coherent framework so that we understand how they contribute to the wider value statements we intend to make. So for example, we should be clear about how we might measure the demand and use of personalisation and that the results of different experimentation in this area are largely comparable. Orthogonal to this, we also need to ensure that any important issues relating to ethics and data protection are clearly understood during these types of evaluation.

Finally we must be able to communicate the value we have identified through the application of the methodology. The FLAME platform is technically complex and many of the stakeholders who have an interest in it will not be reached by the presentation of technical and scientific results. It is for this reason that we need an end-to-end process that engages with a wide range of stakeholders, communicating FLAME value in the appropriate terms.

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2.2 FLAME STAKEHOLDERS

FLAME knowledge is important to a variety of stakeholders in the project since it forms the basis for understanding value from different perspectives. For example, understanding how FLAME services can positively change a user experience during an event can lead to greater engagement and participation. Digital media service providers benefit from understanding FLAME knowledge by understanding how user demand for their services will change and be met by the FLAME platform – and what the resource implications are for them.

We have identified four broad classes of stakeholder:

- **FLAME end users**: these are the people using applications running on the FLAME platform, generally via mobile devices or fixed screens across a city. They will benefit from the enhanced media services the platform will provide and the platform must be configured to anticipate and react to their demands. Understanding the quality of service (QoS) delivered to the end users and the quality of experience (QoE) that they receive is key.

- **Media service provider**: this stakeholder develops over the top (OTT) applications used by the FLAME end users and services which support those applications and which are deployed on the FLAME platform. The media service provider wants to understand the costs of using the FLAME platform and how it can provide benefits to them, e.g. through efficiency, reduction in running cost, new capabilities or enhanced QoE for their end users.

- **Platform provider**: the "platform" in this sense comprises the software components required to support the media services: e.g. orchestration and deployment of services, software defined networking (SDN) technologies, and configuration, planning, monitoring and control systems. The platform provider needs to understand how the constraints of the underlying infrastructure affect the performance of the platform and how best to configure and deploy media services to provide benefits to the media service providers and their users.

- **Infrastructure operator**: the infrastructure operator deploys the FLAME platform on the infrastructure in a smart city. The operator may have competing demands for resources from different stakeholders operating in the city and needs to understand the specific resource requirements that deployment and usage of the FLAME platform brings. The infrastructure operator may also be directly connected to the city governance and is therefore also interested in the benefits FLAME brings to the city's citizens.

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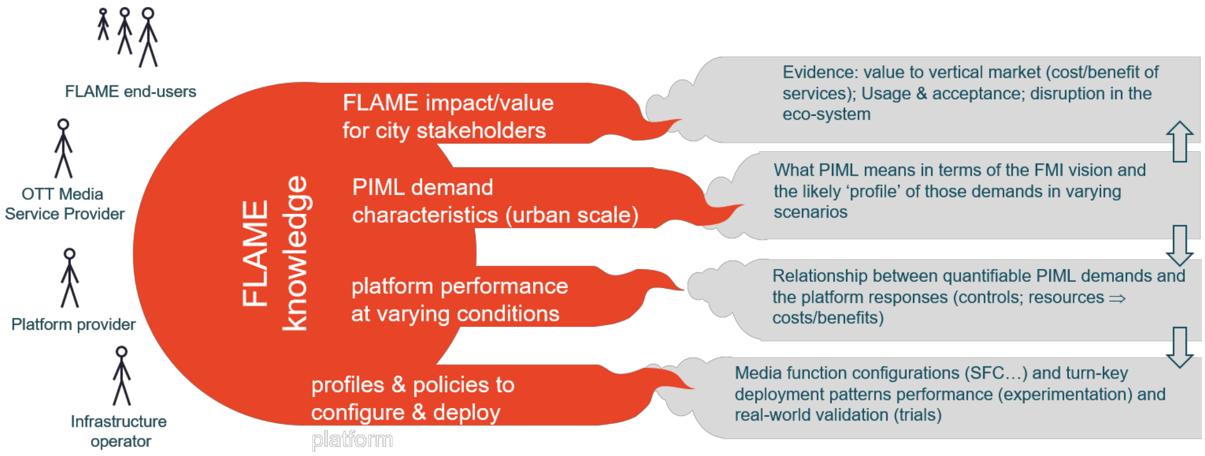

Figure 3. FLAME knowledge model overview

Figure 3 shows how various pieces of general FLAME knowledge feed into specific information of value to the stakeholders. The diagram is deliberately vague in terms of the relation between the knowledge and stakeholders. In performing trials and experiments, we will learn what information is of use to which stakeholder and how they might best access that information.

2.3 FLAME VALUE IMPACT ASSESSMENT PROCESS

As described above, various stakeholders (infrastructure operator, platform provider, media service providers) use FLAME to learn: in this sense they are all "experimenters". Through the process of defining experiment and trial conditions and then the analysis of the observations that we make during these experiments and trials we start to understand how the platform can lead to benefits to one or more of these stakeholders (see Figure 4). That understanding may take the form of certain service configurations or optimisations for a particular stakeholder that can lead to enhancements or reduced costs for them.

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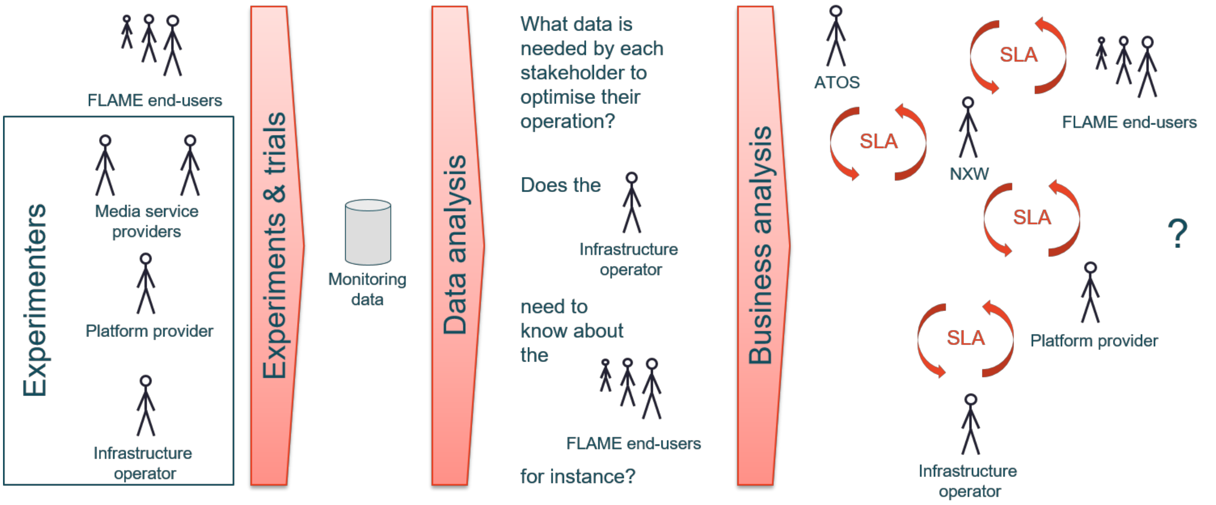

Figure 4. How experiments and trials lead to business models and value.

Today's content delivery architectures support access to high-quality content anywhere and anytime, in a variety of formats with content tagged and enriched using well-structured metadata. This is achieved using over-the-top (OTT) media services which have limited awareness of the network and do not directly interact with underlying network management functions. This creates non-optimal resource allocations causing either overprovisioning costs for network operators or poor QoE for consumers.

For the FLAME platform to be sustainable, business value must be realised. The project is taking the disruptive approach of having no preconceived business relationships: the data gathered during experiments and trials will be available to all stakeholders (within the ethical framework) and the project will first seek to understand the value of the data to each stakeholder and secondly what business relationships are required to realise that value.

For instance, it may be that the infrastructure operator is able to most efficiently provide resources for the FLAME platform if they have direct knowledge about the movements and plans of the individual end users (for instance that a group of people will be attending an event at a certain time). If such data is of value then we must understand the granularity of the information that a stakeholder needs, the privacy and data protection issues, and how in a real world setting of business relationships and service level agreements that value can be realised.

It is this knowledge that then leads to new policies and ultimately new business models defined through contracts and Service Level Agreements (SLAs) that become a part of a provider's offer to market. Such SLAs could exist between 'horizontal' stakeholders (such as media service providers who work together) but also vertically (for instance agreements between the platform provider and infrastructure operator).

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2.4 FLAME KNOWLEDGE DEVELOPMENT PROCESS

2.4.1 Overview

In this section we provide an overview of the development process that underpins the generation of the FLAME knowledge model. Knowledge of FLAME platform demand and usage is expected to emerge as a part of a phased, iterative activity rather than as a linear or waterfall model orientated strategy.

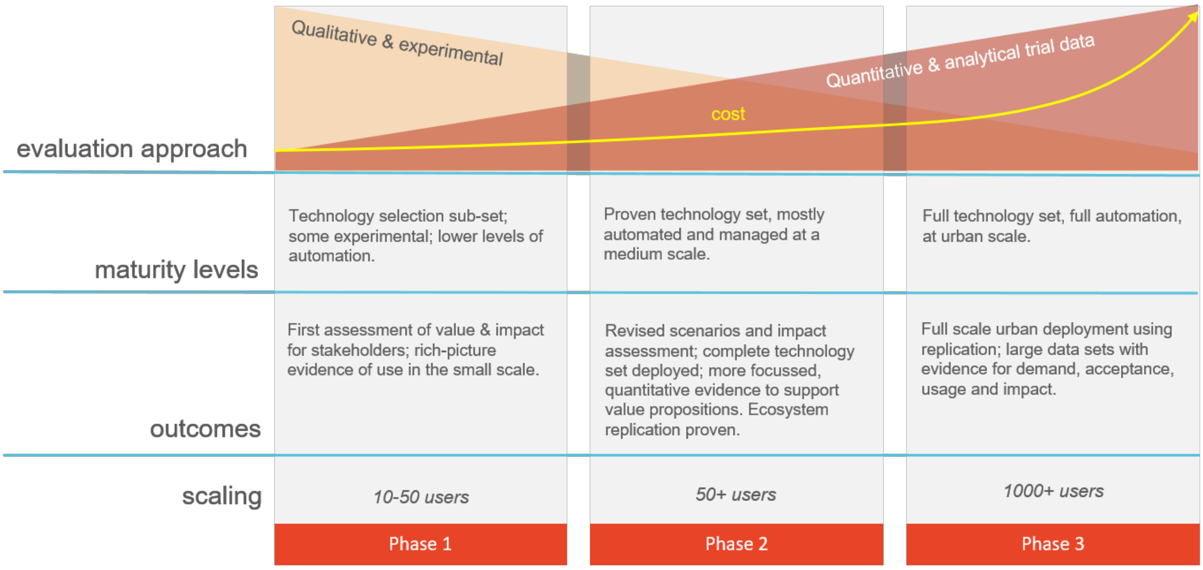

Figure 5. Phases of development for the FLAME project.

The FLAME project proposes three nominal phases of development within which knowledge generation activities take place – each phase represents a successive increase in understanding of FLAME platform use and its application at a particular scale (see Figure 5 above). Phase 1 is intended to establish a preliminary understanding of the value of the FLAME based media services as it relates to the relevant stakeholders of the city ecosystem. Methods here are expected to be qualitative and the technologies available for experimentation and small trials are likely to be a subset of the complete system. Progression to phase 2 will be an indication that there is evidence that media services being investigated are demonstrable and some value has been shown. In this next phase, the experimenter will start evaluating a full media service deployment at a larger scale in order to start answering more focussed questions related to the anticipated value of experience provided by their system. Transition to phase 3 indicates that a firm understanding of the performance and impact of the target media services and user experience has been established at a medium scale. At this stage the experimenter has significantly greater confidence that more costly, urban-scale trials can be deployed on the city infra-structure and that the large data sets they intend to capture will provide the necessary evidence needed to generate compelling statements about the value of the FLAME platform to deliver impactful digital media services.

2.4.2 Experimentation versus trial

In FLAME, we make a methodological distinction between the two terms 'experiment' and 'trial'. The former is an automated or semi-automated evaluation strategy in which components of the FLAME platform are coupled and tested to provide data relating to the performance of the system under certain controllable, emulated conditions (such as network load); users are not included in such tests.

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In the latter case, the focus is on real-world users and the actual demands placed on the FLAME by them. Here the platform is configured based on profile generated from earlier experimentation and its ability to meet the needs of real-world use in FLAME city environments is assessed. A summary of the commonalities and differences between experimentation and trial is presented in Figure 6 below.

At the time of writing, the project is in its early stage of development; so the specific details relating to what type and at which stage experimentation can be carried out in FLAME, if any, have yet to be consolidated. This will be finalised in up-coming work on the platform architecture and vertical validation study deliverables.

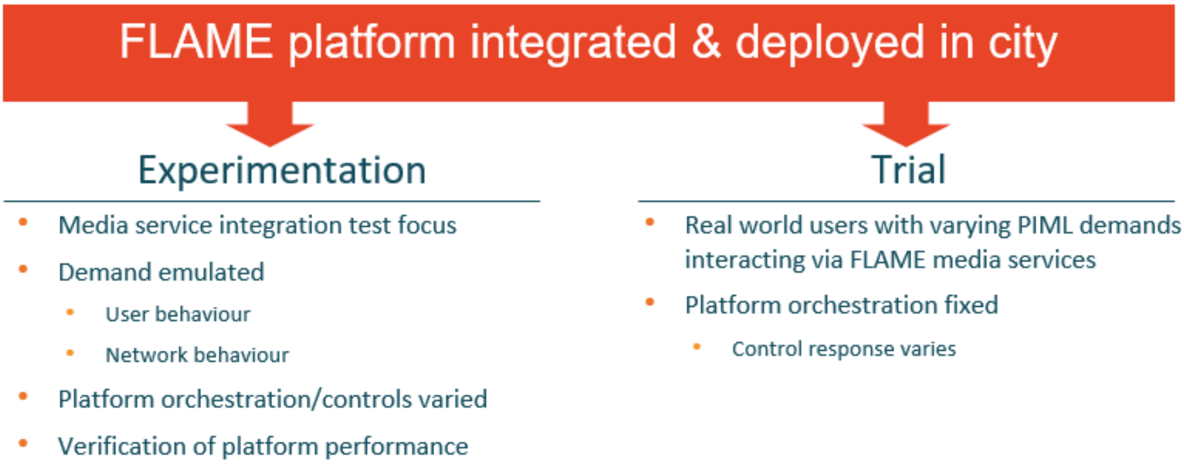

Figure 6. Comparison of experimentation and trial.

In both experimental and trial, the digital media services under evaluation will be integrated with the FLAME platform that has been deployed within a city infrastructure. Experimentation can be used to help understand the likely performance of the FLAME hosted media services under differing levels of demand that might be placed on it in the real-world. Here a demand profile for specific media services could be fixed whilst the platform's configuration (used during service 'orchestration') and control mechanisms (used to respond to particular demands) are varied in order to understand the performance. Results from experimentation could help reduce the risk of failure in real-world trials in which actual users will create demand and experience usage – they provide verification evidence of potential platform performance. Trials contrast with experiments in that the PIML based media service demands and use are generated as a direct result of end-user activity within the city. Before a trial commences, the FLAME platform will be deployed and configured with a particular scale of trial in mind. Once the trial starts, the performance of the media services and the FLAME platform itself will be determined by the control behaviours enacted by the platform to meet real-world use.

2.4.3 FLAME knowledge generation iteration

In the figure below we illustrate the principal elements of knowledge generation within the scope of one iteration. As FLAME knowledge grows and is refined, it is anticipated there will be a change of focus and method selection as iterations pass, leading ultimately to full scale-urban trial execution.

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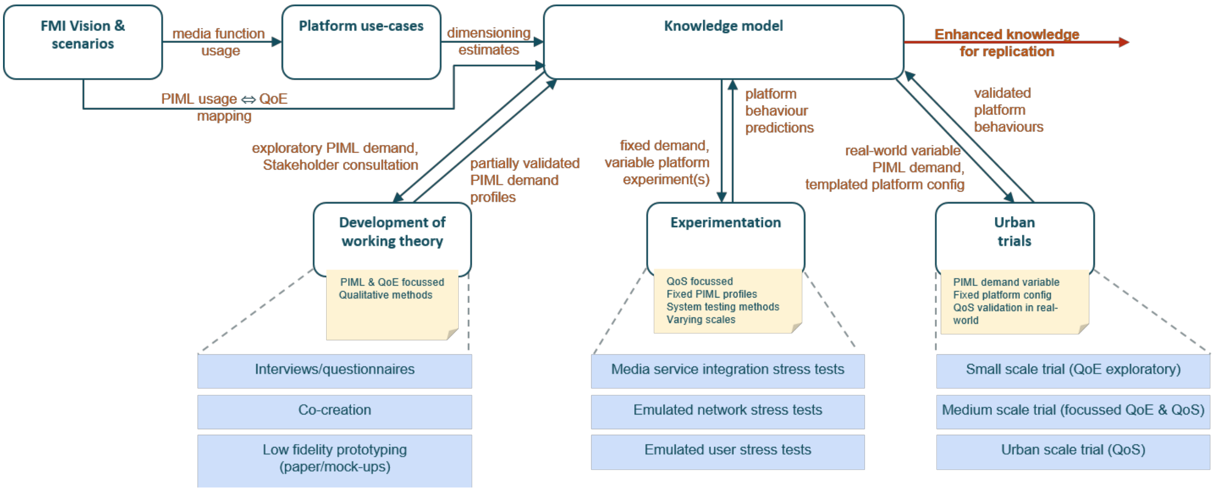

Figure 7. FLAME knowledge generation in the scope of one iteration.

The FLAME knowledge development process begins with inputs generated from the project's scenario based exploration of requirements which in turn will be used to inform anticipated media function usage (described in terms of platform use-cases). FLAME scenarios are presented and discussed in detail in D2.2 "FMI Vision, Use cases and Scenarios"; examples of media use-cases based on these scenarios will be provided as requirements input for D2.4 "FLAME Platform Architecture and Infrastructure Specification". Once the initial scenarios and platform use-cases are realised, the next phase of the process is to develop a working theory of how the demand and use of PIML behaviours offered by digital media services (and supported by the platform) are linked to end-user quality of experience (QoE) and stakeholder value propositions. This investigation is likely to be predominantly qualitative in nature, adopting methods that are appropriate for capturing the 'soft', real-world requirements necessary to form a QoE based working theory. Scenarios play an important role in the development of a 'working theory' of how PIML based experiences could produce interesting impacts through enhancements to the quality of experience in end-users of digital media services operating on the FLAME platform. In the early stages of the knowledge development process, experimenters will use qualitative methods to explore these impacts with the relevant stakeholders. This phase of knowledge development is discussed further in section 2.6.1.

Once a working theory has been established, we have formed an initial understanding of the important media functions required during experimentation and trials as well as some anticipation of the likely PIML demands and their related QoE aspects. We use this first analysis as an additional basis for 'dimensioning' the platform – meaning we define PIML profiles relating demand to media function usage; for example an estimation of the frequency of access to cached content and result network load would be approximated for 'x' numbers of users at a given time. From here experimenters are most likely to move into an experimentation phase that is focussed on the preparation of the digital media services for trials proper through the execution of a series of technical testing procedures. Such tests will be predominantly performance based and focus on the quality of service (QoS) measures that will determine the services' ability to meet the demand profiles generated in the first phase of knowledge generation described above. Such tests may include stress tests on the compute or storage functionality of media services; examination of the service under high network loads; or robustness of system behaviours under use from large numbers of (emulated) users. This phase of knowledge development is discussed further in section 2.6.2.

Trials play a critical, validating role in establishing evidence based knowledge of the value of the FLAME platform. Here demand and usage of FLAME based digital media services will be driven from real-world

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usage; the platform will be configured for such trials based on predictions of how to meet such needs generated by the previous experimentation phase. The application and scale of such trials will depend on the iterative phase of development. Small scale trials will provide an important first insights into the actual use of FLAME based media services and will include both QoE based observations as well as QoS based measurement. As an experimenter's understanding of the behaviours of both end-users and the media services grows, trials will be scaled up and the focus will shift to analytical assessment of service and platform performance. Trial based methods are discussed further in section 2.6.3.

2.5 UNDERSTANDING PIML

In this section we explore in more detail what is understood by the terms *personalisation*, *interactivity*, *mobility* and *localisation* (PIML) and examine their relationship with user experience and interaction with the FLAME platform media services. The realisation of a PIML characteristics through the delivery of FLAME media services is key element in promoting the value of the platform itself. These values, reflected in PIML, encapsulate users' demand for digital content and services that are tailored to their specific preferences and usage context; their expectations that it will ready for them right where and when the need it; and that the context is highly relevant to their changing location as they move around the city. Meeting these demands is complex and has a number of associated costs to stakeholders invested in providing this service (these include content, platform and infrastructure providers). The knowledge generated during the execution of the FLAME methodology will inform generate insights into how the FLAME platform can optimise such services and reduce the costs of delivery.

2.5.1 What is PIML?

2.5.1.1 Personalisation

Users often lack sufficient personal time or motivation to evaluate the potentially overwhelming number of choices that a content provider, e.g., such as a media streaming service, may offer. The issue of digital content overload may be alleviated relying on a basic strategy that provides the same piece of content to each user (e.g., the most popular or trendy object) or developing a personalised approach, whose core is the individual user with his/her specific needs. There are many reasons why a service provider may want to exploit a personalised technology for content delivery, proven by numerous successful applications in e-commerce (e.g., Amazon.com) and in media content delivery (e.g., YouTube, Pandora Internet Radio). From a commercial perspective, a strategy tailored to individual users' needs and tastes increases the number of transactions and at the same time increases the diversity of offerings, suggesting not just popular content but also niche ones. From a user perspective, a personalised strategy allows them to increase two dimensions, often running in parallel: user satisfaction and user fidelity. A well designed system would be able to not only satisfy a temporary need, but also to raise loyalty in customers. In a world where a media provider's competitors are only 'a click away', gaining customer loyalty is an essential business strategy [1].

Numerous approaches have been proposed in the literature to deliver content in a personalised way [4]. A common strategy is to rely on the past behaviour and opinions of an existing user community to predict which media asset the current user will be more interested in. In other words, the idea is that if users shared similar interests in the past, they are likely to have common tastes in the future. The growing popularity of social networks has paved the way for a variant to this "community-based" approach: the content is provided to the user taking into consideration the preferences of his/her friends, based on the insight that people tend to rely more on suggestions from their friends, i.e., people they trust, rather than on suggestions from similar but anonymous individuals [2]. Another popular strategy exploits the characteristics of the actual content to deliver to the user. Content may

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be represented by means of a set of features (e.g., the genre of a song or the visual/audio resolution of content) and the user profile may be defined as an assignment of importance to such features, exploiting user' past interactions with the system. A personalised content delivery strategy must deal not only with user's preferences, meant as soft constraints that may or not be satisfied, but also with hard constraints, i.e., a set of conditions that must be fulfilled [3]. These constraints include both requirements of customers and properties of the product to deliver and an ideal personalised strategy would satisfy both.

Providing personalised suggestions tailored to users' interests requires the definition of a user profile, i.e., a preference model of the user that must be built and maintained up-to-date[1]. The definition of such profile may involve an explicit or an implicit strategy. In the former case, the user is explicitly asked to provide his/her opinion on some objects of the content domain of interest. The procedure of collecting preferences may have different granularity levels: the user may be asked to define a rating for the whole object (e.g., a song), or to express his/her preferences on the features that characterize the object itself (e.g., the musical genre, the composer). The explicit collection of feedbacks usually involves numerical ratings (such as a 1-5 stars scale) or questionnaires. The alternative strategy is to *implicitly* infer user preferences by interpreting his/her actions. This strategy is often preferred being completely effortless in terms of the work required of a customer. For instance, in online merchants such as Amazon.com, the browsing to a particular product page may be viewed as an endorsement for that product. Claypool et al. [3] have found that the time spent on a web page is a statistical indicator of interest and is linearly proportional to explicit rating of interest. The actual strategy used to collect implicit feedback may also depend on the specific kind of object at hand. Consider, for example, the scenario of the well-known video sharing platform YouTube, whose search-and-discovery algorithm has been refactored in March 2012, counting time spent on videos as an accomplishment sign instead of tallying up views.

The analysis of user feedback on the delivered content, explicitly or implicitly expressed, is essential to estimate the performances of a personalised content delivery strategy. A direct comparison between what the a content provider considers as relevant or interesting and what is actually relevant for the user is a potential premise for an optimal tuning or reconfiguration of the delivery strategy in the FLAME platform.

Nevertheless, providers should be aware that providing just accurate suggestions to end users could not be enough to satisfy their needs and create loyalty. This is particularly true whenever the user is supplied with not just a single piece of content but with a list of similar media objects. Since it usually happens that the most accurate suggestions for a user are often too similar to each other, or overspecialised, and risk to become redundant from the user perspective, additional properties should be considered and fostered in the content delivery strategy [9], such as the ability to raise curiosity in the user, surprise him/her or, considering the business perspective, to involve most of the catalogue in the deliver process, fostering the consumption.

[1] In FLAME, we address further contextual adaptations for a user or group of users as part of 'localisation'.

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2.5.1.2 Interactivity

The concept and definition of interactivity has been for over three decades now and views can vary [5]. However, researchers generally agree that the fundamental characteristics of interactivity (described below) provide the general underpinnings of the communication process as it serves (between humans and computers or human and humans via a computer interface) and its contribution to the development of relational outcomes it builds.

One of the most popular views of interactivity, especially in the advertising and marketing fields, is as a medium characteristic. This perspective tries to define the general characteristics of a medium that enhance (perceived) interactivity and allows to attach labels of "low" and "high" interactivity to various media according to their technological features. For example, McMillan et al. [6] identify three core dimensions for perceived interactivity: control, (two-way) communication and time (or synchronicity). Such dimensions are not independent but may overlap. Given these dimensions, [6] further identifies 18 "items" (sub-dimensions) and proposes a study with real subjects that allows to divide such items into three MPI (Measures of Perceived Interactivity) scales: the real-time conversation (RTC) scale, the no-delay scale (ND) and the engaging (E) scale. The RTC items (e.g., enables conversation, enables two-way or concurrent communication) and the ND items (e.g., loads fast/slow, operates at high speed) are mostly *technology* related features that can be directly evaluated in the medium providing the service. The engaging items (e.g., keep/doesn't keep my attention, variety of content) depend on the way users *perceive* interactivity (or lack of interactivity) and their measurement presumably involves users by means of questionnaires or evaluation ratings.

The perception of interactivity as mere medium characteristics tends to ascribe high interactivity to new media (e.g., smartphones) and low interactivity to traditional media (e.g., radio and TV).

Ariel et al. in [5] explicitly moves away from a medium-centric view to a *process*-centric view, where the transmission of information becomes crucial. In [5] it is stated that "interactivity exists as soon as there is an ongoing exchange of information in a communication process" and therefore "interactivity exists in both new and traditional media, whereas the communication process determines the level of interactivity for each exchange of information". In this perspective interactivity is a process-related variable, that is the focus is on the transmission of information and no on medium characteristics. [5] exploits the model for interactivity proposed by Rafaeli in [7], that distinguishes between non-interactive, reactive and interactive responses. Accordingly, three different kind of messages in the communication process are identified. The first type of messages is one-way messages between a sender and one or more receivers: they produce a declarative communication, where messages do not refer to each other. An example in a social platform may be found in a "check-in" operation, which does not refer to previous interactions and do not promote further ones. The second type of messages produces responsive and reactive communication: messages are two-way directional and the receiver may become a sender and react to previous messages. The interactivity is limited however, since messages focus only on the requested information and not beyond it. As an example, consider the "like" operation in a social platform: it refers to previous communication, but does not encourage future one. The third type of messages represent high interactivity: they foster a flow of two-way communication between sender and receiver, each one in turn. Messages may also refer to previous turns and encourage at the same time the continuation of an interaction. For example: "comment" operations intended to keep an ongoing and vivid conversation may be seen as truly interactive. In [5], a similar proposal of the process-centric view for "sociability" of platforms that cannot be seen as social based only on their technological features is explored. As an example, the options such as *like*, *share* and *comment* makes Facebook an actual "social" media, otherwise it would be just a social enabling platform. At a deeper level, two Facebook pages might differ from each other in their level of sociability, if the conversation on one page is vibrant while another page lacks exchange. Sociability is

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therefore regarded as proportional to the number of exchanges and users of a platform: the higher the number of (active) users and exchanges in a platform, the greater the level of sociability of that platform. In other words, a social media platform by itself serves as affordance technologies to enable various levels (low to high) of sociability and interactivity. Based on this insight, [5] proposes as ideal a communication setting characterized by a high level of both sociability and interactivity. In other words, it must be characterized by many users and many interactive exchanges.

The perspectives introduced above (technology-centric, user's perception, and process-centric) shouldn't be considered as mutually exclusive. As an example, [8] promotes a broad definition of interactivity as the possibility to exchange information between users or between users and a medium and the possibility for users to manipulate the communication, both in content and form. In particular, the multidimensional scale of items developed by [8] refers to video game interactivity and its validity is corroborated by five independent studies with real users. The more general level of the scale, which can be easily extended beyond video game domain, is the responsiveness of the system, meant as the speed and appropriateness of system's reactions to a user's input. In addition, the scale is made of numerous objective (feature-based) dimensions, such as advanced graphic options, sound effects, display resolution and refresh rate, text and audio dialog. Other dimensions look more subjective and dependant on the user perception and explicit feedback. As an example, the user in [8] is asked to express his opinion on questions such as "I feel physically in the game world", "I feel immersed in the experience" or "The system responds intelligently".

2.5.1.3 Mobility

A non-optimal allocation of digital resources in a network infrastructure may negatively affect both user experience because of latency time and service providers that often have to face overprovisioning costs. Mobility awareness is regarded in FLAME as an answer to escape these phenomena. In other words, enabling a service provider with mobility would help meet user's requests such as "I want digital content as near as possible to me" or "I want digital content available to me as soon as I need it".

Supporting user's mobility means that the content delivery system must know and exploit user (or group of users) location (in some form of abstraction; this could be physically based or logically based[2]), changing over time. This implies that a mobility-aware delivery strategy cannot work without an accurate prediction of user's movements. The modelling of user movement in space has been generally carried out through a *Markov chain*, i.e., a mathematical model for randomly changing systems. Specifically, in standard Markov chains the prediction of the next/future status only depends on the current status. In case of mobility, this would imply that the prediction of next user's position depends only on his/her current position. User movement has been modelled as a standard Markov chain in Long Term Evolution (LTE) Femtocell Network [10] [11] for handover procedure and decision strategy. In this case, the concept of status has been replaced with *point of interest* (POI). The main drawback of standard Markov chains modelling, i.e., its memoryless, is overtaken in enhancements of standard Markov chains, which, for example, rely on *n* previous locations. These enhancements have been exploited in [12] and [13]. In Markov chains modelling, the starting status of the user is generally defined to encode information such as initial state, velocity and distance.

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[2] Physical representations may come from GPS data; logical representations from a location on a network topology.

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For the acquisition of the low-resolution or 'logical positioning' of users on a network node, WLAN has increasingly being regarded as the method of choice for mobility-aware systems [14]. In fact, most mobile devices are nowadays equipped with built-in WLAN capabilities and an increasing number of hotspots can be found in urban areas. Other mobility-aware systems that require higher resolution positioning of individuals rely on GPS [15].

The evaluation of the mobility-awareness of a content delivery system requires an analysis of prediction *accuracy*, meant as the ratio between the number of correct predictions and the total number of predictions. In other words, the delivery strategy must correctly predict the next user position (or next *m* user positions) in order to provide digital content in the right physical place and for example, enable content that moves together with the user. In analogy with the dropped-call rate in telecommunications [13], the evaluation of a mobility-aware content delivery system would consider the dropping probability in content provisioning, estimating the fraction of cut off provisioning. As the target of mobility awareness can be found in the reduction of latency time and provisioning cost, the evaluation would include an analysis of both dimensions before and after the adaptation of the mobility-aware content delivery strategy.

2.5.1.4 Localisation

The localization concept in FLAME can be regarded as the awareness of actual user *location* in the content delivery and caching strategy. Location is not limited to geographical position, but broaden to the concept of *context*, i.e., the ensemble of physical position and current background situation, which in turn is made of people surrounding the user and ongoing events.

A context-aware content delivery and caching strategy rather than being personalised towards an individual user's preferences, try to adapt itself to the context in which the user or a group of users are. This does not mean that personalization and localization are mutually exclusive dimensions. As an example, a "hybrid" delivery strategy could first prioritize the content relevant to current context and then order it according to individual user's preferences. Lane et al. in [16] provide an example of a local search engine that makes use of this kind of hybridization. They start from the assumption that a senior and a teenager located at the same position in a city and issuing the same query (e.g., about entertainment), reasonably would like to have different search results, and, accordingly, they foster the local search strategy with behavioural profiles and preferences of the user. They also define users with similar behavioural histories and enhance the system with community-based information.

In FLAME, the awareness of localization in the delivery strategy is seen as a shortcut for the resource consumption: the resources relevant to the users' context would receive a high priority. The benefits that such strategy would give, for example reducing latency, should be compared with user satisfaction, since a trade-off could exist between them. It may happen, in fact, that mobile users are just interested in popular content across the whole user population. Presumably most of the users would have a positive feeling with the content relevant for the background context, but the actual percentage of such users should be estimated.

For collecting users' feedback, both the explicit and the implicit strategies introduced above for the personalization dimension, could be considered. The use of implicit feedback is preferable also in this case, since it does not ask for any effort by the user. The analysis of user feedback allow a potential estimate of the accuracy of the context-aware delivery strategy: meant as the ratio of delivered relevant or interesting content count for the users against the total number of delivered media assets.

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2.5.2 PIML and privacy

Within the project the privacy related issues and impacts associated with the use of FLAME's media services and platform (from a multi-stakeholder point of view) are treated as 'first class' citizens in the development of FLAME knowledge. For example, it is recognized that in the many cases of an end-user's PIML based interaction there will be a trade-off between their use of a media service and some potential release of private information (this could be in the form of a personal preference; the transmission of user generated media; their location in a city, etc.). In such cases the project will adopt a 'privacy by design' approach in the design, implementation and deployment of the related media applications, services and FLAME platform functionality from the outset. The specific trade-offs and protection mechanisms as they relate to the realisation of these services and trial designs will be explored in more detail as the project progresses. Protection afforded to end-users will be guided by the project's adherence to the NEC requirements set out in two confidential deliverables. These deliverables provide further information of the appropriate processes and constraints relating to informed consent; confidentiality; relevant legislation; data collection, processing, retention and export; and ethical guidelines.

2.5.3 A simple PIML example

To illustrate some PIML behaviours that could be provided by digital media services running on the FLAME platform, let us imagine a new, virtual city guide application and service. This guide offers large numbers of visitors the opportunity explore cultural aspects of the city through a variety of engaging, interactive experiences (for example, using Augmented Reality views running on their mobile devices).

City guide: personalisation

As the city guide progresses, some visitors start to make choices about how the information is presented to them. Perhaps some prefer just an audio stream; whilst others want an Augmented Reality (AR) presentation. FLAME ensures that the right media functions are available to deliver, at the edge of the network, content in its preferred form to the user's city guide application as it is requested.

City guide: interactivity

As users freely explore the environment, they want to directly share their experiences with others (through live digital content). This might include live video of themselves next to interesting city artefacts or sharing some 'revealed' digital content (perhaps collaboratively interacting with an augmented 3D model). FLAME ensures that this shared content is efficiently routed between users so that shared experiences can be experienced 'live'.

City guide: mobility

Many groups of users use the city guide - these groups' memberships may change as they move through the environment. FLAME ensures that their content follows individuals and caches new guide content to their next location ahead of time. Digital content can also be considered as mobile in the sense that it may translate from one device to another. Imagine that in some parts of the city touch sensitive, wall mounted displays present a 'zoomable' map of the local area. In this case, FLAME provides an edge-based service that transforms the user's mobile UI into a second display for the wall mounted device to use to render (at very low latency) additional content to the user for their point of interest.

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City guide: localisation

The city is a dynamic space: content and events are continuously changing. FLAME ensures that digital content caching and delivery can be prioritised based on immediate context (i.e., most recent and/or closest to user location). For example, when the city guide application requests images of the most recent digital media posts based on user location, FLAME will route these requests to content delivery management services that are deployed nearest to the user's location.

2.5.4 What is QoE?

Quality of experience is a complex concept and not easily defined because it is composed of many elements, some of which are directly observable and quantifiable whilst others must be collected using indirect and subjective means. There is no singular, definitive definition of QoE – it is often viewed as a network of inter-related aspects that connect a person to the world via interactive experiences the aspects of which include but are not limited to:

- Real-world context
    - The physical environment in which the activity is set
    - The activity the user is currently engaged with
    - The social context of the activity
    - The resources and costs associated with the activity

- Personal experience
    - The user's understanding of the activity they are engaged in
    - The user's understanding and aptitudes with the technologies that mediate an activity
    - Usability related to interactions with technologies associated with the activity
    - The user's previous experiences and attitudes towards similar activities

These aspects play an important role in shaping user expectations and perceptions of use during an interactive experience. These are further influenced by system behaviours and performance, characterised in terms of quality of service (QoS) and include:

- Performance measures related to user interaction, such as:
    - User Interface (UI) responsiveness
    - Task completion time

- Performance measures related to the network supporting the service, such as:
    - Bandwidth
    - Latency
    - Capacity & coverage

- Performance measures related to supporting services, such as:
    - Data processing time
    - Data access time

Therefore we understand QoE as a contextually dependent set of factors relating to a user and her experience (current and past) that will influence their perceptions of use of the digital media services being provided at a particular level of QoS. For example, if we wanted to understand some aspect of user engagement as a critical QoE component during city based game play, we might collect and analyses QoE measures of focussed attention (using the Flow State Scale [17]) with QoS measures of

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average UI response time and network latency metrics to understand how the later might impact the former.

2.5.5 Understanding PIML demand, usage and QoE

The FLAME knowledge model needs to link PIML based applications and services with the behaviour of the platform and user experience; this is described as a process, see Figure 8 below.

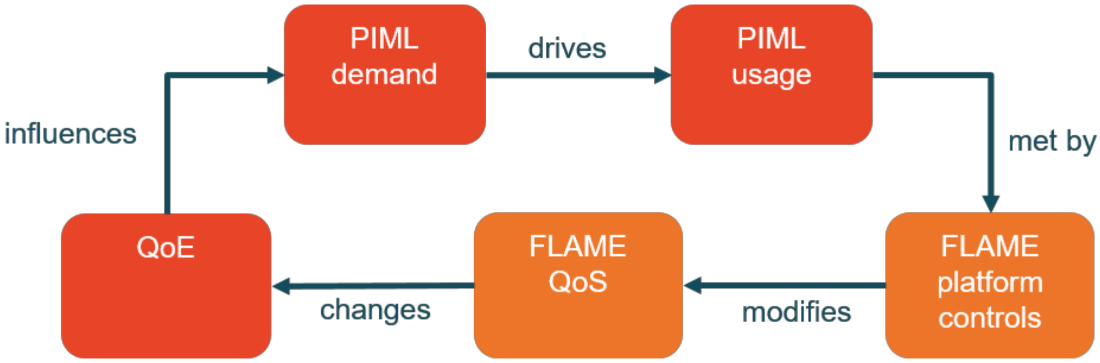

Figure 8. Process linking PIML demand, usage, FLAME platform and QoE.

In this relationship we assert that end-users' activity with the FLAME city ecosystem generate a *demand* for PIML based experiences through their interaction with applications that in turn make requests for associated digital media services supported by the platform. This demand is translated into *use* through the processing of media functions and dynamic behaviours of the FLAME platform controls to meet those demands at a particular time. These behaviours will modify the QoS of the digital media services with the aim of optimizing user experience; this in turn will change interactive outcomes for the end user and influence their perceptions of QoE.

Insight into the relationships between PIML demand and usage, FLAME platform behaviour and QoS and user QoE must be achieved through observation and analysis of data from various sources and in varying forms – see Figure 9 below.

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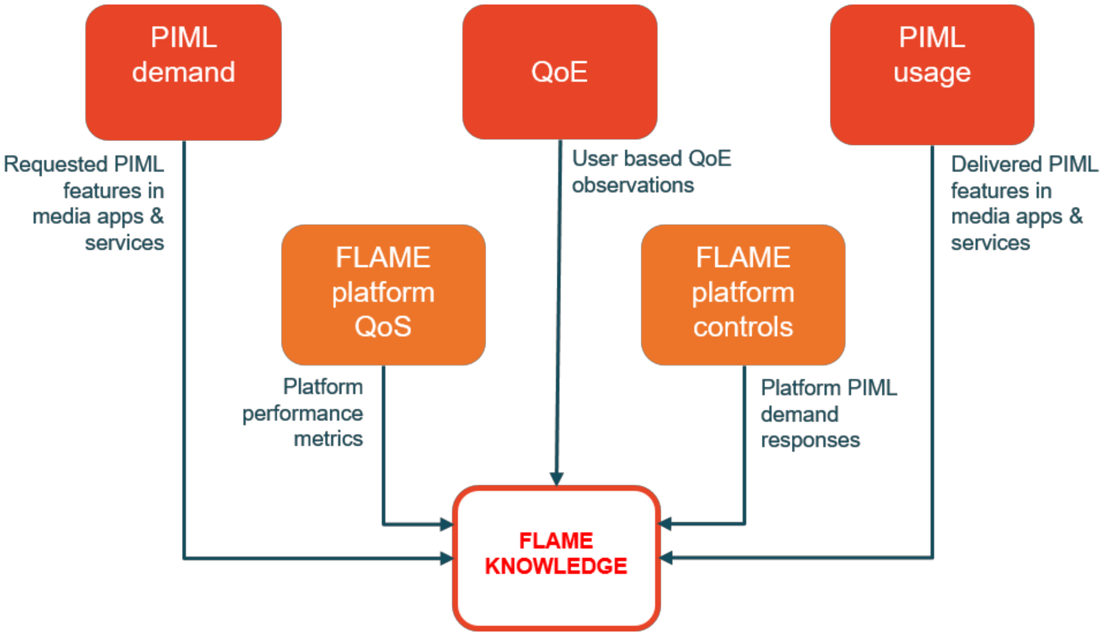

Figure 9. PIML, QoE and FLAME platform knowledge contributions.

An experimenter will collect data relating to PIML demand by observing the requests made by their digital media applications and services for FLAME media functions. The frequency and variance of such requests could be representative of the demand for a particular aspect of *interactivity* or *mobility*, for example. The fulfilment of this request is captured as part of the FLAME media services and platform's response and as such characterises its usage. In this case, the experimenter may be interested in the overall time to get a result back from the media service or some aspect of the quality of the digital media returned (such as bitrate). Running concurrently with these measures, the FLAME platform control behaviours will be observed in order to understand how its various resources are being managed (such as the provisioning of media caches on the mobile edge) to meet PIML demands being created by end-users. Changes to the performance characteristics of the platform and its digital media services as a result of platform control behaviours, expressed as QoS measures, are also captured. Finally, user generated reports of QoE (for example, captured as time-stamped Mean Opinion Scores) will provide a qualitative view of their experience during a live trial.

As an aggregate, this data provides the experimenter with a rich view on the demand, use, performance and quality of experience of their media applications and services running on the FLAME platform. In Figure 10, we present a high-level view of how the FLAME platform itself is expected to support data collection and analysis for experimentation and trials.

End-user facing applications invoke digital media services deployed on the FLAME platform that is configured by experimenters – each one of which represent a stakeholder who have an interest in the outcome of the experiment. Direct feedback from users with respect to their quality of experience will be collected using existing, third party data collection channels already widely used for mobile and web-based application monitoring (such as Google Universal Analytics). Demand and usage metrics for PIML based digital media functionality will be captured by the media services themselves and sent for logging by the FLAME experiment management run-time. Control behaviours enacted by the FLAME platform in response to demands, along with QoS measurements relating to compute and storage; service end-point and routing; and network switching management layers will be also continuously monitored by the experiment management run-time process.

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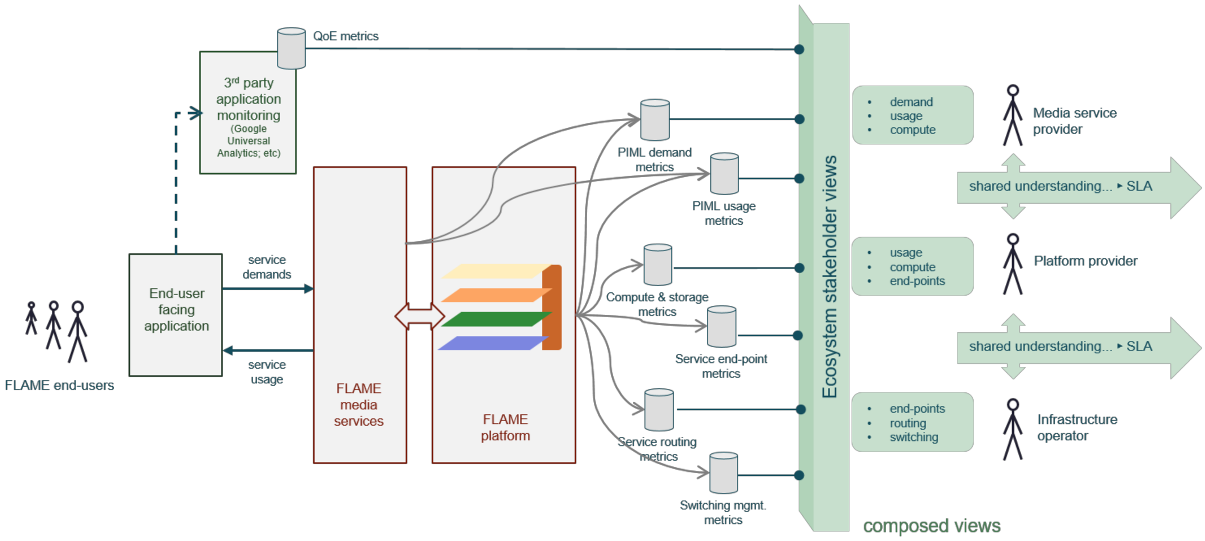

Figure 10. A high-level view of FLAME platform supporting data collection and analysis.

Over the course of an experiment or trial, this data will be accumulated in appropriate data stores and will be made available for visualisation and evaluation via a composable ecosystem stakeholder (data) view. This view will allow stakeholders to select from any of the available data sets generated and use them to execute an analysis. In our example from Figure 10, a media service provider has an interest in understanding how the demand and realised usage of one of his services is impacting on the compute resources being dynamically provisioned. From the platform provider's experimental perspective, it may be that the compute resources and their end-point distributions are of interest in order to understand load balancing. Finally, from an infrastructure operator point of view, a greater understanding of how to optimize network routing and switching of traffic to support best delivery of the results of the media function compute is interest here.

The open view of the data generated during an experiment or trial offers all experimenters the opportunity to gain a shared insight into how the FLAME platform and media services can be optimised to deliver high quality, PIML based user experience. As discussed in section 2.3, this then leads on to the definition of policies that can be used to enforce service level agreements at a business level. Readers are directed to the forth-coming FLAME deliverable D2.4 "FLAME Platform Architecture and Infrastructure Specification" for more technical information on the architecure of the platform and its support for the processes described above.

2.6 KNOWLEDGE GENERATION METHODS

An overview of the FLAME knowledge generation process was discussed in section 2.4.1 in which we outline the iterative process that supports the journey toward urban scale study of the vertical validation experiments for the project. Here we further explore some of the potential methods that can be employed to support knowledge generation at each of those stages: *working theory development*; *experimentation* and *urban trials* (see Figure 11 below for a summary of their characteristics).

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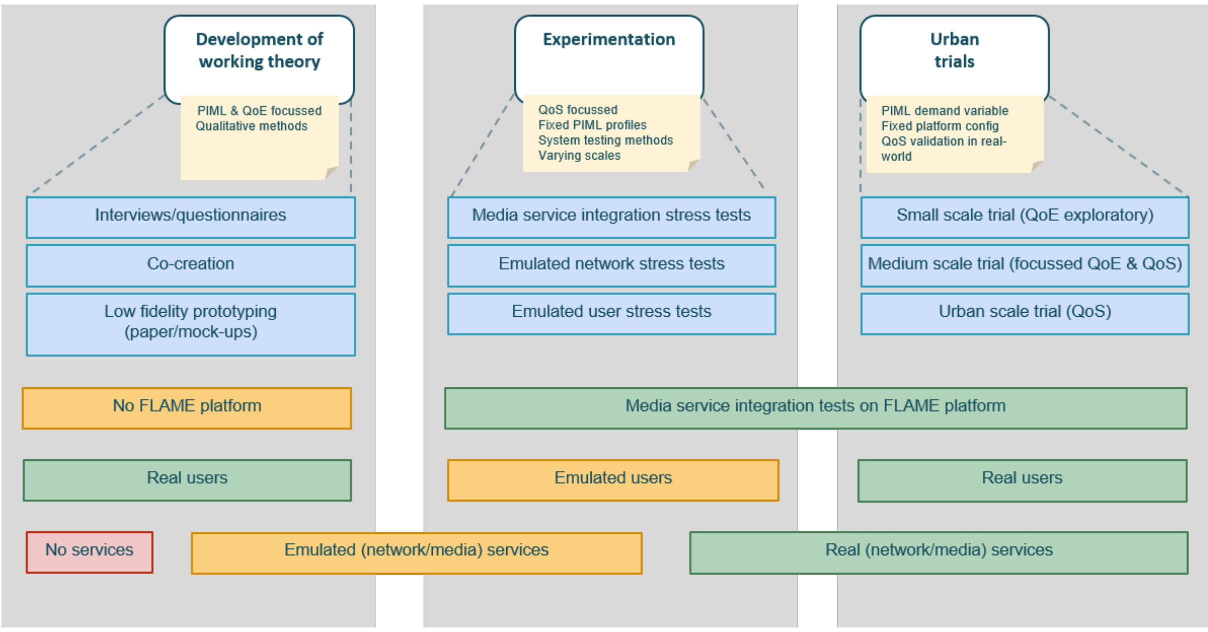

Figure 11. Overview of knowledge generation methods.

2.6.1 Working theory development methods

An important early objective of this methodology is to establish a preliminary understanding or 'working theory' of the value of the media services being evaluated from the perspective of the relevant stakeholders in the city ecosystem. A working theory in this context should express a relationship between the PIML based behaviours that the target media services offer to qualitative aspects of end-user experience that will create value to one or more stakeholders. In order to establish such a relationship, it is necessary for experimenters to engage with city stakeholders and elicit this understanding. In this section we explore a number of methods for this purpose.

2.6.1.1 Stakeholder interviewing

A common approach to understanding quality of experience in a specific context of interactive system usage is to hold interviews with stakeholders whom have an interest or may be impacted by the arrival of a new interactive system or online service. A typical interview would include a presentation by the experimenter on the system and/or service they intend to provide and a storyboard based walk through of the scenarios that it is intended to support. The focus of the scenario based walk through should be the user experience and its anticipated outcome, rather than a technical discussion on the implementation of the system. In turn, those stakeholders are then invited to ask questions and explore aspects of the scenario further so that a common understanding can be reached.

Interviews provide an opportunity to present the high-level concepts of what is being proposed and time for the interviewees to reflect on what it might mean for them from a number of points of view. These are likely to include understand who the likely beneficiaries of the new service might be; an exploration of the pragmatics of actually deploying and accessing it; the costs involved; how existing services and revenue streams might be impacted through its use. Through executing this discourse, a qualitative understanding of user experience and its relationship to the potential value of the new service being proposed can be elicited.

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2.6.1.2 Co-creation exercises

Co-creation exercises takes the process of eliciting an understanding of end-user QoE and value impacts further by actively engaging stakeholders (which typically include potential end-users) in the early design phases of the digital media application/services. This process begins in a similar way to the interviewing process in that the initial concepts and scenarios are provided first by the experimenter to set the scene; an opportunity for questions and answer then follows.

Once a satisfactory level of understanding has been reached, stakeholders are invited to take part in a variety of techniques to develop the design ideas behind the user experience themselves. This activity should ideally take place at least once directly in the physical space where the user experience is likely to occur – this provides an immediate context for evaluating its value. During co-creation, participants actively contribute design ideas including: identifying currently unmet needs from their experience of existing services; the description in narrative form of activities or interactions that they believe would enhance user experience; visualisations of what they would like to see in their user interfaces; the emergence of new relationships between stakeholders as a result of their new design ideas.

2.6.1.3 Low fidelity prototypes

In some cases experimenters may already have a set of design ideas and user experiences already partially developed and that are now in need of some early evaluation from real-world stakeholders to mitigate against the risk of low user acceptance of the new media service much later in the project. Low fidelity prototypes may include the use of paper-based wireframe designs of user interfaces or very simple prototypes that display static content and respond to basic interactions (such as button clicks) but do not provide any real functionality. In each case, it must be made very clear to the stakeholders involved that the designs being presented are 'throw away' artefacts and should not be considered as representative of the final application or service.

Low fidelity prototyping can be a more powerful means of exploring the interactive aspects of proposed scenarios with project stakeholders, especially in cases where the potential behaviours of the application and service may be complex. Using low fidelity prototypes goes beyond just presenting what might happen during a user experience. Participants should be encouraged to examine the user interfaces presented and be asked to demonstrate how they would attempt to interact with the UI in order to achieve some goal. Questions about their immediate perceptions of its affordances relating to use and the utility of the digital media or information presented should be asked during this process. It will quickly become apparent whether or not the design of the artefact and services presented to them makes any sense: problems with usability and the services' alignment to their own expectations of the value of such a system will often emerge as a result of this interactive process.

2.6.2 Experimentation methods

As can be seen in Figure 11, the primary distinction of the experimentation methods compared to the "working theory development methods" outlined above is that experimentation (in our definition) occurs on the FLAME platform deployed in a city. On the other hand, experimentation involves no human end users (as distinct to "trials"). As already stated, it is not clear at this stage what experimentation, if any, can actually be done in the FLAME project as the focus in FLAME is very much on user trials.

Experimentation would begin with a formally released version of the FLAME platform which has already passed unit tests, contract, integration and end-to-end tests all performed on FLAME's integration and qualification infrastructure (separate from the city infrastructure).

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Experimentation would be performed before trials to gain an understanding of the performance of the system and how it behaves under different conditions. The experiments should help in defining the control policies which are required to ensure the system reacts appropriately to differing demands. In this way, experimentation reduces the risk of trials: testing aspects before the expense of coordinating real end users in a live trial.

Experiments should be repeatable: a defined set of test conditions should result in a consistent outcome (accepting certain well-defined but stochastic behaviour). This is distinct from trials where users will inevitably behave unpredictably.

Should any experimentation be performed, an outline of some of the tools we expect to be useful follows.

2.6.2.1 Load testing

As noted above, the primary distinction between experiments and trials is that experiments do not involve real end users. As the platform's primary purpose is to provide enhanced features and experiences for end users, experiments will need to include emulated users providing demand (or "load") for media services and hence the platform features.

There are many load testing solutions available. We will consider using Taurus [18], an open source test automation tool that extends and abstracts leading open source tools including JMeter, Gatling, Locust.io, The Grinder, and Selenium and helps to overcome various challenges. Taurus provides a simple way to create, run and analyse performance tests and can be configured using simple scripts such as:

```
execution:
	concurrency: 10
	hold-for: 2m30s
	ramp-up: 1m
	scenario:
		requests:
		- url: http://my.mediaservice.com/
		  method: GET
```

It is likely that most user emulation will be done by interacting directly with the media services which support the client applications (e.g. by making REST API calls as in the example above). Should it be necessary, tools exist to drive the client software itself, directly emulating the users' button presses in user interfaces. Appium [19] for instance can drive iOS, Android and Windows apps using the WebDriver protocol developed as part of Selenium [20].

2.6.3 Trial methods

Trials provide experimenters the opportunity to both validate the operation of their digital media applications and services and also to generate important new knowledge that enhances the project's understanding of the value of the FLAME platform from a range of stakeholder points of view. In order to maximise the quality and consistency of trial outcomes, the FLAME methodology provides a series of milestones for experimenters to reach in the course of designing, planning and executing experiments:

1. Trial design & review

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2. Ethics, data protection & risk assessment
3. User & stakeholder engagement
4. Planning
5. Execution
6. Reporting

Each trial within the project will have its own specific objectives and knowledge related outcomes, so the methodological guidance provided within FLAME will not be a 'one size fits all' solution. Instead the guidance related to each milestone will be applied and specialised as appropriate in each case. As the project progresses, additional understanding regarding best practice for trial based evaluation will be refined and added to our knowledge base.

2.6.3.1 Trial design

An important first step toward a successful trial outcome is to clearly define the objectives of the trial and a criteria set by which it is possible to evaluate success (these may be both quantitative and qualitative in nature). Objectives will vary, depending on the iterative phase in which the trial is situated (i.e., early trials will be small scale; involve limited numbers of users and may be oriented towards technical validation and QoE assessment). The formalisation of these objectives may be defined in terms of verifying specific technical behaviours or performance levels or in other cases may relate to the collection of specific metric based observations that will service to prove or disprove a hypothesis.

A well-defined set of trial objectives should be included in a trial design document that sets out the methods of user engagement (see section 2.6.3.3); deployment requirements and plan for the trial (see section 2.6.3.4); the demographic profile of intended participants; observational data types and methods and analysis approach intended to understand the results. Once an experiment has specified their approach, the documented trial design will be reviewed by the experiment's assigned "mentor" (for open call participants) to ensure alignment with the project's overall impact objectives – recommendations will be fed back to the experimenter to enhance the anticipated outcomes.

2.6.3.2 Ethics, data protection & risk assessment

Additional assessment of the trial design must also be taken from the perspective of ethics, privacy, data protection and risk appraisal: this will be carried out by the FLAME Ethics Management Board. A review of the potential impact on trial participants must be carried out to ensure fair treatment of individuals is maintained; that appropriate consent has been obtained and that any significant risks to individuals or organisations are identified and managed. Careful consideration of the creation, use and storage of data during the trial must also applied with respect to data protection law. For more information on this process and guidelines on these matters, please see deliverables D1.1 "NEC – Requirement No. 1" and D1.2 "DEC – Requirement No. 3".

2.6.3.3 User & stakeholder engagement

FLAME trials require participants in the city. Recruiting individuals to take part in a trial is a non-trivial task that often requires significant engagement effort well ahead of the proposed time when the trial will take place. Experimenters will need to identify target communities who will be in the city that are most likely to meet their participant demographic and define channels through which they can be

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reached. City based stakeholders involved in the trial may be able to assist in this process as they are likely to be connected to these groups. Additional support from the project's dissemination activity may also be provided in terms of the provision of promotional material and events.

2.6.3.4 Planning

Successful execution of a trial requires significant planning and coordination between the various stakeholders in the project and city. A trial design must include a schedule that details key preparatory milestones that should be achieved before execution begins; these include:

- Agreement with the city infrastructure and platform providers of the intended use of the FLAME platform for the trial and the anticipated resources and time frames required.
- Agreement to carry out the trial with any city stakeholders that may be significantly impacted by the activities carried out during its execution.
- If required: agreement to an attendance schedule with any participants who have volunteered to take part (this applies mostly to detailed QoE studies where their physical presence with the experimenters is required).
- Pre-trial deployment testing and verification. Experimenters are strongly recommended to factor in a number of days ahead of the trial proper to 'dry run' their trial deployment in the city.

2.6.3.5 Execution

Much depends on the nature and scope of the trial to be known before a detailed protocol for execution can be defined. However there are a number of common aspects that should be considered in all cases. For example, irrespective of trial scale, all participants should be made aware of the fact that they are taking part in a trial and be asked to acknowledge their consent to do so. For small scale trials, this consent may be obtained on a one-to-one basis with the experimenter using a paper based consent form. In larger trials, this consent should be obtained by other means, for example by electronics means via a web form. Participants should also be made aware of their use and rights to the data generated during the trial and of their option to stop participating at any time. Once their participation is over or the trial has concluded, where possible participants should be provided with some form of de-briefing with respect to the trial's objectives.

2.6.3.6 Reporting

Finally, some consideration must be given ahead of time as to how the outcomes of the trial will be reported and to whom. Experimenters should keep in mind that the presentation of outcomes should be tailored in a format that is appropriate to the audiences they have in mind. For example, highly analytical, data orientated analysis may be suitable for technical and scientific dissemination but may not communicate well with city stakeholders who may be more interested in the outcomes in terms of value impact to their business or communities. Reporting should also be considered for accessibility to the wider, general public and appropriate materials prepared for dissemination via the project's Internet based channels, including the website. In planning and designing for a trial, it is therefore imperative that experiments link their objectives with a strategy for communicating the value of the work both to their stakeholders and for the FLAME project as a whole.

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3 INDICATIVE VALIDATION EXPERIMENTS

3.1 PARTICIPATORY MEDIA FOR INTERACTIVE RADIO COMMUNITIES

3.1.1 Evaluation summary

3.1.1.1 Stakeholders

Stakeholder	**Interest in experiment/trial outcome**
Media partner	Learn how to use infrastructure for participative media creation
Event visitors	Participate in story creation around live events
Event organisers	Keep track of activity around event and create engaging experiences
Media service providers	Providing services for e.g. automated content analysis, smart caching, etc...
Infrastructure provider	Learn how to develop infrastructure for supporting media scenarios
Platform provider	Link infrastructure to experiments

3.1.1.2 Indicative trials

Trial #	**Scale**	**Approx. experiment lifetime**	**Key demonstration points**
1	Small	1-2 days	Technical validation of participative media experiments
2	Medium	Dependent on event calendar	User validation of participative media experiments
3	Urban	Duration (part) of festival	User validation in a real environment, simultaneous, real and scalable (changeable groups and crowds during city event).

3.1.2 Indicative PIML characteristics

The table below summarises the PIML characteristics this experiment intends to address; full PIML coverage is not necessarily expected from within each of the driving, validation experiments.

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PIML characteristic	Potential demand and use observations from scenario
Personalisation	User selection and filtering of favourite artist/workshop/etc based on chosen activities and digital context captured by them (for example, through the use of face recognition). Personalised digital movie usage; use of personalised digital signage.
Interactivity	Communication between users through chat and A/V content sharing through the Spotlight app. Decision making process through interactive polls. Use of AR game content through object recognition.
Mobility	The journey of all the visitors is tracked, from before the event, travelling to the event, mobility during the event and leaving the event area. At all times the visitor can be a participant of the festival, in or outside the event area.
Localisation	Digital content filtering based on user location and events occurring locally. Use of safety measurements and visualisation relating to crowd control. Location based aggregation of digital content in the production of post-event media.

3.1.3 Indicative FLAME experimentation objectives

Media/FLAME platform service	Experimentation objectives
Location services	Accurate geo location, personalised towards one individual
Media contribution service	Distribute HQ media data towards digital signage and mobile devices
Media processing services	Adding metadata (tags, quality, …) automatically to hq media
Connectivity	Connect to large crowds real-time simultaneously.

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3.1.4 Indicative FLAME trial objectives

PIML characteristic	Potential QoE outcomes	Interest to stakeholders
Personalisation	By actively contributing to the covering of the festival, the user gets a more personal participate relation with the event.	Personal relationship with the end user. Covering the festival in a broader way through the eyes of the visitors. Give more accurate visible information real-time.
Interactivity	Direct interaction between friends, other visitors, the event organiser and the media partner	Communicate in a direct way with all stakeholders, create interactive tools to steer the festival (gamification)
Mobility	Be a participant of the festival on or away of the event area. Before, during and after.	Crowd control during the event for emergency measurements.
Localisation	Finding friends and venues.	Filter digital content based on location. Crowd control. Gamification by localisation.

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3.2 COLLABORATIVE INTERACTIVE TRANSMEDIA NARRATIVES

3.2.1 Evaluation summary

3.2.1.1 Stakeholders

Stakeholder	Interest in experiment/trial outcome
Transmedia Experience Provider	Enabling new forms of interactive transmedia experiences
Local Organization	Observe the potential of city-wide interactive, collaborative, transmedia narrative-based experiences
Smart City infrastructure / platform operator	Evaluate feasibility and prepare infrastructure for a service offering of that kind
End user / experiment participant	Experience city in an engaging and interactive way

3.2.1.2 Indicative trials

Trial #	Scale	Approx. experiment lifetime	Key demonstration points
1	Small	1+ days	Technical validation
2	Small	Days to weeks	User validation in a real environment with focus on user experience
3	Urban	Weeks to months	User validation in a real environment, potentially simultaneous, real time and scalable.

3.2.2 Indicative PIML characteristics

The table below summarises the PIML characteristics this experiment intends to address; full PIML coverage is not necessarily expected from within each of the driving, validation experiments.

PIML characteristic	Potential demand and use observations from scenario
Personalisation	Use and development of the user model (knowledge gained & locations visited) to

	provide a personalised and optimised path for user to experience city-wide quest. User actions influence narrative progression resulting in creation of personalized story experience.
Interactivity	Interaction with virtual characters and physical locations as part of engagement with the story telling process.
Mobility	Interaction with the story telling narrative while moving through the city.
Localisation	Narrative information is associated with physical locations. The physical locations provide context to enhance the narrative.

3.2.3 Indicative FLAME experimentation objectives

Media/FLAME platform service	**Experimentation objectives**
User authentication	Authenticate user with both the smartphone-based story telling application as well as with FLAME platform.
User geo-position	Determine user geo-position using available information. Also determine position with respect to the location of FLAME media services integrated within the scenario.
Transmedia content caching	User can retrieve transmedia content provided in designated locations within the FLAME infrastructure. The aim is to enable a novel transmedia experience combining the smartphone interface as well as physical objects within the city.

3.2.4 Indicative FLAME trial objectives

PIML characteristic	**Potential QoE outcomes**	**Interest to stakeholders**
Personalisation	User is guided to have an optimal experience of a story-based city-wide quest.	User interest and engagement is considered. Narrative content authored by the application provider may be optimized for particular users.

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Interactivity	User has agency to influence story progression.	User is empowered to engage with elements of story and participate in authored experiences.
Mobility	User remains connected to narrative while moving through city.	User may be guided or informed at any time via the mobile application.
Localisation	User experiences narrative elements that are embedded in physical locations.	User may relate elements of the story to physical locations and services within an urban environment.

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3.3 AUGMENTED-REALITY LOCATION-BASED GAMING

3.3.1 Evaluation summary

3.3.1.1 Stakeholders

Role	Interest in experiment/trial outcome
Players	The users (players) of the online multiplayer location-based trading game are the participants of the experiment. They are recruited and asked to play the game over a certain time period. Optionally, the players could be asked to stress test certain elements of the game or find game play related loopholes and deadlocks, which would break the gaming experience and fun for other players. The players might be rewarded for the participating or simply enjoy participating and playing the game. In a multiplayer location-based trading game, players are engaging in a shared virtual game world, integrated into the real world. Players are interacting with the game world, with its virtual economy, as well as with each other, which creates a social environment suited to study socio-economic player behavior.
Game developers	The main goal of the game developers is to understand all aspects their game. When developing a game and devising game mechanics and components, it is often impossible to foresee how all game mechanics act together and facilitate fun, entertainment, and motivation. The user's playing behavior is often unpredictable. It is therefore crucial to iteratively test and evaluate game play and game mechanics with real users while the game is developed. These playtesting sessions are typically followed by altering and adapting game mechanics or fine-tuning game parameters. Such parameters could be the behavior of the supply and demand model for the virtual economy in a resource trading game. For games that target a large user base of hundreds or more and players engaging simultaneously in the same game instance, trials become even more essential to understand how many players interact together and how the game evolves over time. This is often impossible to simulate as both, the (unknown) player behavior as well as the (unknown) game behavior needs to be calibrated and simulated at the same time. Long-term and large-scale trials allow the developers to observe the game evolve, inspect the socio-economic behavior of the players as they engage with each other and with the game elements over a long period, and collect feedback from the players through questionnaires. Finally, conducting long-term trials allows the developers to inspect long-term motivation of the players.

3.3.1.2 Indicative trials

Trial #	Scale	Approx. experiment lifetime	Key demonstration points
1	small	1 week	Core game functionality

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2	medium	weeks	Longer-term core and social game functionality
3	large	months	Full game functionality and long-term player motivation

3.3.2 Indicative PIML characteristics

The table below summarises the PIML characteristics this experiment intends to address; full PIML coverage is not necessarily expected from within each of the driving, validation experiments.

PIML characteristic	Potential demand and use observations from scenario
Personalisation	Players log in to their personal account that tracks their progress in the game. A shared leader board allow players to share their personal scores with others and compare their progress with the progress of other players.
Interactivity	An online multiplayer location-based trading game allows its players to interact with a virtual game world that includes a virtual economy as well as to interact with each other. The game's graphical user interface running as part of the game client on a smartphone is the primary form of interaction, and directly and permanently connects the player to the game world. AR components allow the users to interact with the game through 3D objects virtually and seamlessly integrated into the real world. Potentially, social game features such as chat, sharing, or resource trading could allow players to interact with each other through the game world.
Mobility	Player movement is essential to the game. At all times, the game server needs to know each active player's GPS location. Depending on (unspecified) game mechanics, this information could be continuously (anonymously) broadcasted to the all players. In order to create an immersive experience for the players, communication to the game backend needs to be low latency. Additionally, a real-time video stream of a player's screen as the player interacts with the game could be broadcasted/multicasted to public infrastructure displays in the player's vicinity to allow other players and even pedestrians to follow the player's actions.
Localisation	The virtual game world and its elements are seemingly integrated in the real world. As such, players experience the virtual world localized as if linked to the real world. Specifically, in the trading game, different types of resources may appear in the game as if influence by the real world. For example, water resources may be found near lakes and rivers, snow and ice may be found in high altitudes, and wood and soil may be found in nature environments.

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3.3.3 Indicative FLAME experimentation objectives

Media/FLAME platform service	**Experimentation objectives**
Real-time video streaming to close displays	The objective of the experiment is to see what quality of video can be streamed to displays for a given infrastructure. The real-time video stream can be replaced with a pre-recorded screen capture video. The number of video stream sources as well as the number of displays can be varied to evaluate different scenarios. Framerate, resolution, and compression level of the video can be varied to explore bandwidth requirements. Video compression level, resolution, and latency add to the video quality.

3.3.4 Indicative FLAME trial objectives

PIML characteristic	**Potential QoE outcomes**	**Interest to stakeholders**
Personalisation	Players log in to their personal account that tracks their progress in the game. A shared leader board allows players to share their personal scores with others and compare their progress with the progress of other players.	Players: Allows the player to make a stronger connection to the game world. Developers: Analyse detailed player behaviour, e.g. personal scores, to tune and improve game mechanics.
Interactivity	An online multiplayer location-based trading game allows its players to interact with a virtual game world that includes a virtual economy as well as to interact with each other. The game's graphical user interface running as part of the game client on a smartphone is the primary form of interaction, and directly and permanently connects the player to the game world. This means the players game state is constantly synced with the server backend. All game changes such as price of resources are available all the time. AR components allow the users to interact with the game through 3D objects virtually and seamlessly integrated into the real world.	Players: Interactivity is closely tied to the how immersive a game is and thus essential to the player's QoE. Developer: Measuring and recording how the player interacts with the game is essential to the game developers as they might directly conclude valuable insights about how well the game is working. User interface design as well as game design aspects can be improved if such data is available to the developers.

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	Potentially, social game features such as chat, sharing, or resource trading could allow players to interact with each other through the game world.	
Mobility	Player movement is essential to the game. At all times, the game server needs to know each active player's GPS location. Depending on (unspecified) game mechanics, this information could be continuously (anonymously) broadcasted to the all players. In order to create an immersive experience for the players, communication to the game backend needs to be low latency.	Players: sync the player's real world with the virtual world. Failing of mobility services would break the game. Developers: Player mobility data may allow the developer to tune geospatial game mechanics parameters.
Localisation	The virtual game world and its elements are seemingly integrated in the real world. As such, players experience the virtual world localized as if linked to the real world. Specifically, in the trading game, different types of resources may appear in the game as if influence by the real world. For example, water resources may be found near lakes and rivers, snow and ice may be found in high altitudes, and wood and soil may be found in nature scenery.	Players: Localization enhances the players QoE as it ties the virtual world closer to the real world. Developers: Allows implementing interesting location-based game mechanics.

3.4 PERSONALISED MEDIA MOBILITY IN URBAN ENVIRONMENTS

This experiment will explore how consumers participate and access broadcast media on the move through various personal devices, from fixed and mobile type. In particular, we will not focus on how personal videos at home (in local VoD/NAS) will follow users, but rather how Media Service Providers can serve users on the go (within the Smart City) and how they can build a media distribution service chain while users move in the smart city.

The concept of the scenario is "My Screen follows-me": as long as the user moves from one fixed video/audio device (e.g. at home) to personal mobile devices (e.g. tablets, smartphones) and moves within the urban area, he/she can get his/her streaming moving with him/her.

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This experiment aims at validating a business model in which a media service provider can rely on a Smart City infrastructure to deliver a personalized media service for its users while they are on the go within the Smart City.

The primary technical objective of the experiment is to evaluate the feasibility of a personalised media service in the Smart City infrastructure based on FLAME platform. We expect the capability to dynamically instantiate media distribution service chains to serve moving users

Subsequently, through the collection of QoS/QoE measurements and of the various stakeholders' feedbacks we aim to evaluate the business feasibility for such a service and the potential uptake of the experimented technology from Smart City infrastructure operators or local/regional service providers for personalized media services offer in the Smart City.

3.4.1 Evaluation summary

3.4.1.1 Stakeholders

Stakeholder	Interest in experiment/trial outcome
VoD service provider	Evaluate the viability of a FLAME-based infrastructure to better deliver service within the Smart City
VoD technology provider	Tune and enhance the OTT application platform for VoD to work in Smart Cities
Smart City infrastructure owner	Evaluate feasibility and prepare infrastructure for a service offering of that kind
End users/experimenters	Benefit of personalized media streaming services

3.4.1.2 Indicative trials

Trial #	Scale	Approx. experiment lifetime	Key demonstration points
1	Small	3 days – 1 week, with possibility to be repeated	Test the "my screen follows me" from home to smart hand-held devices in the Smart city Test the capability to swipes media from a fixed video/audio device at home to personal mobile devices (e.g. tablets, smartphones) and move within the FLAME urban area while continuing the media fruition on the move

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			Verify that the FLAME platform is capable to dynamically instantiate flows in the infrastructure that can match the the QoS/QoE requirements for the media streaming
2	Small	3 days – 1 week, with possibility to be repeated	Test the "my screen follows me" from home to buses/public transport in the Smart city. Test the capability to optimize the caching and distribution of contents when the user jumps on a touristic bus/public transportation and FLAME flows and contents caches are are re-allocated to serve him/her on-board
3	Urban	3 days during a relevant event in the city	Test the "my screen follows me" during a community event in the Smart City (e.g. MWC in Barcelona). Use the FLAME-empowered city infrastructure to test a video streaming from public events and the swipe-based transfer from digital signage posts to personal hand-held devices and vice versa while on the move across the smart city

3.4.2 Indicative PIML characteristics

The table below summarises the PIML characteristics this experiment intends to address; full PIML coverage is not necessarily expected from within each of the driving, validation experiments.

PIML characteristic	**Potential demand and use observations from scenario**
Personalisation	With *My screen follows me* the user will select the personal devices into which to consume the media while moving within the urban area This requires a dynamic adaptation of the transcoding service chain that FLAME platform is expected to implement in coordination with the media service application. In case of TVCC streaming, there is also the possibility to select the TVCC camera to stream and remotely control zoom, rotation etc. to implement a personal view of specific zones under control.
Interactivity	Interaction in this experiment occurs along different lines • For media creation, the user configures and manages personal DVR and access to personal library of recordings

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	• Also there could be the need to validate performances of review/fast-forwarding/rewinding of contents and their impact on media buffering and FLAME reaction in terms of infrastructure For TVCC live contents also the reaction time to zoom-in/out and camera movement is an important aspect of personalization that need to be measured
Mobility	Mobility is mainly related to users' moving the Smart City space covered by FLAME platform, where the media service chains will be allocated and adapted on-demand The main aspect of mobility to be observed here is related to the support with quality of *media* streaming while swiping from one device to the other (i.e. with involvement of transcoding functions) and while moving across the Smart City (i.e. while roaming from one cell/Network Access Point to another one)
Localisation	Location information for the user (e.g. a user close to a shop window, in a mall, etc.) could be used to add on the media some specific advertisement /notification for personal promotions/adverts based on user preferences.

3.4.3 Indicative FLAME experimentation objectives

Media/FLAME platform service	**Experimentation objective**
Media service chain orchestration	FLAME platform is capable to instantiate dynamically the media streaming service chain across the various city access points, composed of various media server functions, caching functions and transcoding functions. QoS and QoE parameters are evaluated to measure performances and users' acceptance of such a service. QoS parameters to measure on media server side: • Average Bit Rate – the average bandwidth being consumed by the video stream from origin server to the client viewing the content • RTD • QoE based metrics to monitoring • Display quality (fidelity): is the image quality sufficient for the device's screen size? • Transport quality (stalling):

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	○ Start Time – the elapsed time from when “play” is pushed to when video starts on the screen ○ Re-buffer Rate – the number of times a re-buffering event occurs during viewing ○ MOS- does the video play smoothly?
Media service chain dynamic re-adaptation	Based on user mobility within the Smart City, the media service chain is automatically re-planned upon trigger from the application (based on QoS/QoE degradation) to re-establish a good quality of streaming
Location services	Depending on the availability of user location information within the Smart City (through the FLAME platform) and some specific profiling of user preferences, specific advertisement /notification for personal promotions/Ads are shown to the user terminal

3.4.4 Indicative FLAME trial objectives

PIML characteristic	**Potential QoE outcomes**	**Interest to stakeholders**
Personalisation	Tyoe of media service of major interest to users (TVCC, personal media contents streaming from VoD, etc.) Perceived performances for the service and user acceptance (i.e. willingness to pay for such a service)	VoD service providers, VoD technology provider and Smart City infrastructure operators can derive a market size for personalized media services in the Smart City and determine investments, technical enhancements to the platforms, features of major interest.
Interactivity	Major media interactivity type requested Performances of the media streaming and usage of the underlying infrastructure (i.e. number of retransmission, throughputs, number of flows, etc.)	VoD service providers and VoD technology provider can derive useful information on functions of major interest in their service and the
Mobility	Number of users served from a network access point	VoD service providers, VoD technology provider and Smart City infrastructure operators can derive useful planning

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	Infrastructure performances at network access points	information for their infrastructure and service
Localisation	User localized within 10 meters from a shop window	Shop owners can interact with the Smart City platform to post their offers and better target promotions for their potential customers

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4 NEXT STEPS

The FLAME project has defined the first version of its methodology that provides experimenters with a process and structure within which experiments and trials can be iteratively designed and executed. Knowledge generated from the application of the methodology will enhance our understanding of the value of the FLAME platform.

Experimenters in the project will now use the scenarios defined in D2.2 "FMI Vision, Use cases and Scenarios" and use these as the basis to begin designing their experiments and trials. Each will describe how a particular set of digital media services, running on the FLAME platform architecture (see D2.4 "FLAME Platform Architecture and Infrastructure Specification") could be used to enhance user experience in an urban city context and create evidence based knowledge to support FLAME impact propositions. An updated version of the FLAME methodology is expected early in the second year of the project.

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5 CONCLUSION

Our methodology serves to support experimenters in the design and execution of experiments and trials in a consistent and structured way such that understanding of the value of the FLAME platform can be progressed. Readers should now be aware of how the methodology relates to other activities in the project through reference to the FLAME information model. The four broad classes of FLAME stakeholder identified in our methodology have been used to examine the potential benefits and impacts of FLAME platform use. A developmental process has been specified that defines a path from small to urban scale trials, supported by methods that inform and refine that progress iteratively. The characteristics of PIML have been explored and their demand and use related to the anticipated behaviours of the platform and media service performance. Methods and strategies in support of both experimental and trial based evaluation have been discussed and indicative examples for the vertical validation experiments outlined.

The project is now in a position to move forward with the design of its first set of vertical validation activities and able to make significant advances in the definition and realisation of the platform architecture with respect to requirements for supporting the FLAME methodology.

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