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A Roadmap for IoT Impact Assessment Reserachers

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***Abstract*—*The Internet of Things (IoT) is regarded as one of the prominent technologies of this century which has acquired lots of attention in society, industry and academia. Meanwhile, the past decade has witnessed a paradigm shift in the way research councils and funders view the impact of such technologies. However, there is no one single strategy for evaluating impact, rather there are many approaches for impact assessment. Grounded in international best practices, this paper presents an impact assessment roadmap for IoT researchers, illustrated with indicators of impact evidence. The paper provides an insight into the underpinning theory and methodology for practical application of the roadmap with reflection on a European Commission smart cities project; MONICA (Management of Networked IoT Wearables – Very Large Scale Demonstration of Cultural Societal Applications)*

Keywords— IoT, Methodologies, Impact Assessment, smart living

1. INTRODUCTION

A wide range of IoT technologies can be used for smart living. Examples include IoT enabled sensors with different data capabilities (video, audio and other data types), resource constraints (wearables, Smartphones and Smartwatches), bandwidth (UWB and M2M), costs and deployment (wearable, mobile, fixed, and airborne) in addition to actuators (lights, LED, cameras, alarms, drones, and loudspeakers).

For instance, wearable devices with sensing, actuating, localisation, and communication capabilities can support several applications by being deployed as actuators (LEDs) through automated closed-loop solutions and can be integrated with more powerful Smartphones and/or Smartwatch apps.

An integral part of deploying IoT technologies in large projects is assessing the impact such technologies have on society. The emphasis on demonstrating such impact has grown in the last ten years. We have moved from a situation where Impact is the serendipitous outcome of research to one where impact has to be planned and explicit rather than accidental and implicit. This focus on impact has led to both a change in practice among researchers and a change in behaviour of research funders, with a great emphasis on achieving excellence with impact in terms of demonstrable contribution to society, culture, the economy or quality of life beyond academia (RCUK, 2011; HEFCE 2007).

2. A ROADMAP TO IOT IMPACT ASSESSMENT

Building on best practices in the field and reflecting from own real world experience of designing impact assessment framework; we present a roadmap for IoT impact researchers to help them establish a basis against which IoT technologies impact and future progress could be evaluated, measured, and valued. To help achieve that, this roadmap produces a framework for assessing different types of impact of the project in a clear, rigorous and accessible manner to all stakeholders. Each road map dimension defines one important milestone of assessing IoT impact.

2.1 Methodology

This section discusses the methodology used in structuring the assessment framework, the evidence needed to fulfil the assessment, and the methodologies used to gather this evidence. The proposed IoT Impact Assessment Framework is informed by our theory of change explained below. Our theory of change is essentially a comprehensive description and illustration of how and why the desired change is expected to happen in a particular context. Our theory of change is focused on mapping the causal linkages between what a certain IoT project does (its activities and interventions) and how these lead to desired goals being achieved. Accordingly, our framework is composed of five stages:

- Stage 1: Planning for Impact

- Stage 2: Understanding Baseline Environment
- Stage 3: Baseline Data Validation
- Stage 4: MONICA Impact Indicators Development
- Stage 5: Implementation & Refinement

Below, we explain how this proposed framework integrates with our mission of impact assessment by going through each of the proposed stages.

2.2 Stage 1:Planning for Impact

Ensuring that the IoT project actually makes a difference means an emphasis on demonstrable contribution to society and economy and a tangible improvement to quality of life, beyond academia. This is achieved via innovation and collaboration. Ensuring that the IoT technologies deployed in the project achieve impact means working with those in a position to provide guidance and use the project innovations to change practice. Accordingly, the project should show evidence that it took steps in all areas to build mutually beneficial and enduring partnerships which achieve positive outcomes.

An effective Impact Assessment Framework should ensure that the IoT project Impact is assessed via the following criteria:

a) Nature of the impact

The nature of the expected impact is defined by the influence, effect, demonstrable contribution, change, or benefit resulted from the innovation. This covers the IoT technologies effect on an individual (such as clients staff), a community (such as the cultural industry), and the creation of new products (represented in the technological innovations proposed by the project).

b) Relevance of impact

The context within which impact takes place must be relevant to each client's requirements in terms of providing tangible contributions to solving the stakeholders' problems. To proof evidence of relevance of impact, the IoT project should demonstrate:

- Developing and deploying IoT ecosystems that comprehensively address real end users' challenges.
- Tailored operating platforms that adapt to the different conditions of each client participating in the project.

c) Pathways to impact

The Impact Assessment Framework should ensure a breadth of impact is achieved. The context within which impact takes place must be broader beyond academia in the realms of the society, economy, public services, and quality of life. Below, we discuss different aspects of impact MONICA aims to achieve.

(i) **Cultural impact**

IoT impact researchers should show how the project contributes to the performance, interpretation, and enjoyment of cultural activities, bringing new experience of current and future events for the purpose of making a change and inspire the broader creative economy.

(ii) Social impact

The framework should provide evidence that the IoT project addresses significant challenges including issues of limited resources that can contribute in improving quality of life. It should show how the IoT technology allows sharing data of IoT sensor networks and wearables with citizens and civic groups. It should make it clear that through the IoT technological innovations, the project aims to contribute to actions for positive social interactions, such as enhancing sound experience, controlling noise, managing security when dealing with large crowds, and engaging citizens to participate in smart cities platforms. To provide proof of societal impact, IoT researchers need to provide evidence of impacts where the beneficiaries are the wider public or a particular public audience.

(iii) Economic Impact

Show how the project seeks to have a positive impact on the economy through the development of new technologies that improve efficiency and provide solutions to the challenges faced by both public and private sectors. IoT innovations employed should help to streamline business processes and improve efficiency. To provide evidence of economic impact, the researcher needs to demonstrate impacts where the beneficiaries include businesses or organisations, which undertake activities that may create wealth, and that the deployed IoT technology has created new ways for businesses to serve their customers

(iv) Regional Impact

In the case of international projects, the impact researcher needs to show how the project is deeply embedded in which countries and how many citizens the project serves. The researcher should evidence that the project would cater for the needs of different cities and offer several business models based on certain packages for innovators and entrepreneurs to serve as a development toolbox to support the integration of Smart City platforms. To best achieve that, projects partners

with several bodies across the designated cities to grow the economy of our region and enrich the life of our community by taking all opportunities to invite its involvement and participation.

2.3 Stage 2: Understanding Base-line Environment

Understanding the environment where the IoT technology will operate is an integral part of the Assessment Framework. Understanding the baseline environment should include the followings:

a) Considering what is currently in place.
b) Understanding the needs of stakeholders and drivers for change
c) Understanding the external factors that may influence the realisation of the expected outcomes and related impact.

In this stage both the stakeholders and base-line data are identified, as below.
i) Understanding Stakeholders
Stakeholders are those who can positively or negatively affect the output of the project. It was very important for MONICA Project to identify and engage with the key stakeholders at the very early stages of the project. This includes: who are the key stakeholders? What are their needs? Why should they support the change? What are their current attitudes and behaviours?
ii) Base-line Data
Baseline data are these data that are collected to help improve our understanding of the current conditions of the area investigated, as well as how the project needs to be implemented. The effect of baseline data considerations can focus minds to appreciate and measure the impact. Whenever and wherever possible, efforts should be made to attain and collect baseline data.

- Characteristics of Baseline Data:

In attempting to understand the impact of an IoT project, baseline data are essential to our understanding. The process of collecting data needs to be valued and appreciated, as data and information are of little value if it is not of specific use to their stakeholders. Baseline data should be meaningful and focused on answering the project main requirements. Thus, the starting point for assessing the project impact is 'good enquiry questions'. Good inquiry questions should tell us what was our starting point, how far we progressed, which direction to be taken, and where do we want to be, and how will we know when we get there.

- Baseline Data Collection

i) Participants' Selection and Recruitment:

The sampling technique used in recruiting the MONICA project participants was 'Cluster Sampling'. In this technique, participants are selected in groups, and a sample of participants is randomly selected from each cluster. In MONICA, we have several clusters per pilot which include:

- Event Managers and Production Staff
- Event Stewards and Security Staff
- Event Other Staff (Police, Medical, etc.)
- Community
- Neighbourhood and Residents
- Event Customers and Visitors

ii) Data Collection Methodology:

Mainly there are two approaches to collecting data. The first is quantitative in nature, mainly numeric. The second is qualitative, which helps us answer the 'why' question by providing more depth in understanding an issue. Below we provide examples of both techniques.

Qualitative Techniques:

a) Interviews: Interviews are mainly conducted on one to one basis. They can be structured, or semi-structured. They need to be well managed and the interviewees need to be kept on topic, yet allowing them to provide reach data. It is advisable that interviews be reviewed and recapped periodically to check understanding. Also leading questions should be avoided.
b) Focus groups: This technique brings together a group of people. Good facilitation is needed that allows for managing dominant speakers to provide platform for everyone to provide their input.
c) Observation: In this technique, a set of events are observed without any involvement.

Quantitative Techniques:

a) Surveys: These are mostly used for mass data collection. Usually, they need significant effort to achieve good and representative response rates. Particular care needs to be given to the design of the questions.

b) Indicators: This technique depends on selecting and monitoring a set of figures as indicators of impact. This type of data can be misleading if represented without a narrative.

Examples of various formats to be used to increase response rate and to capture a wide population include:

- Online feedback – via social-media e.g. Facebook and others, Google Analytics,
- Online questionnaires – via survey monkey, Google forms, etc.
- Mobile device apps e.g. for Android
- Instant feedback via wearable (wristband)

Base-Line Data Handling

All data are collected and archived in ways that make it easy to revisit. The repository used for data storage should be described. For example, in MONICA project, this was the Basic Support for Cooperation Work (BSCW) document management system. Restricted access is given to the workspace. Information about security regulations and data protection procedures should be available.

2.4 Stage 3: Data Validation

This stage covers the process of validating the data collected via the pilots. This is a very important step to ensure the relevance and usefulness of the baseline data. The validation process is performed through triangulation. Triangulation of data is essential to improve the validity and reliability (quantitative data) and the rigour (qualitative data) of findings. The Impact Assessment Framework should utilize methodological triangulation through the adoption of a mixed methodology drawing on indicators that involve both quantitative and qualitative data. Triangulation is assured through the active participation and inclusion of key stakeholders in the process via workshops managed by the impact assessment team. The inclusion of multiple data sets in the framework data gathering process also allows for triangulation of the data sources. Interpretation of the findings through the professional lenses used by all of the disciplines involved in the project will assure triangulation of interpretation and analysis. This supports the findings being validated through a range of methods including: case studies, quantitative data analysis (statistical regression) and qualitative data analysis (thematic analyses).

Outcomes Classification

This step is concerned with getting a confirmation from the pilots on the new terminologies and classifying the expected outcomes into:

a. Primary Outcomes

b. Secondary Outcomes.

A primary outcome is defined as an outcome that is likely to be achieved for the pilot. A secondary outcome is that which might be achieved b but to a lesser extent than a primary outcome. Example of such form used for the MONICA project is presented in the table below.

Table 1: Primary and secondary Outcomes

Domain A: Staff Related Goals	P	S
1. Communication		
2. Incident/ Fight detection		
3. Portability of devices		
4.		
5.		
Domain B: Audience Related Goals		
1. Crowd Movement flows/ issues in Entrance and Exit		
2. Safety		
3.		
4.		
Domain C: Neighbour Related Goals		
1. Traffic issues		
2. Sound/Noise		
3. Safety		

2.5 Stage 4: Impact Indicators Development

This section discusses the development of IoT projects impact indicators. Impact indicators are the specific, observable and measurable change that represents the achievement of an impact. Indicators need to demonstrably show progress towards the project objectives. They need to assess, communicate, and lead the change. Effective indicators must be measurable.
Indicators are either numeric indicators or qualitative ones that would define success. As an example, the development of MONICA indicators was informed by:

- Scenarios (stories) developed of Pilot case studies in consultation with stakeholders.
- Scenarios and use cases defined in technical work packages from which requirements are drawn and subsequently impact indicators selected.
- A series of validation meetings to capture information about current processes and procedures and to verify initial performance indicators.
    - The main goal of these meetings is to a) verify pilot agrees with suggested indicators, b) confirm what information has already been made available to MONICA, c) identify events that the impact team can observe and to d) give pilot the opportunity to suggest / participate in any further data collection.

- A combination of interviews, focus groups, and observations.
- The formation of an outline of indicators which then are collated and evaluated at a local level within each pilot. The full set of indicators are summarised in the table below.

Table 2: Key Performance Indicators (KPIs)

Pathways to Impact	*Impact Indicators*
Socio-Cultural	Participant approval rate Acceptance of technology Adoption of technology Perception of service / technology Satisfaction with technology / service Number of security and health incidents Incident response/resolution time Incident severity
Economic	Audience figures and visitors' numbers at the events demonstrable collaborations with industry Business performance measures. Demonstrable cloud interoperability Product (e.g. App) downloads Product (e.g. App) usage
Social	Number of complaints Types/categories of complaints Ratio of complaints to positive comments Measures of improved social quality, welfare and inclusion Information about the number and profile of people engaged and types of audience.
Environmental / health	Nuisance (noise and general low-level petty crime) Congestion (traffic) Congestion (crowd)
Academic	Innovative methodologies, equipment, techniques and cross-disciplinary approaches Contribution to excellent research and/or academic advancement

Training highly skilled researchers

2.6 Stage 5: Implementation and Refinement

This stage discusses the implementation of the Impact Assessment Framework, and the iterative process for its refinement. This process is mainly concerned with breaking the assessment into more manageable tasks of data collection and validation in light of the expected social, economic, technological and environmental impact. This section also proposes a set of templates for the report of impact activities.

Table 3: Impact Planning Template

Goals	Partners	Methods				Resources		Evidencing
Impact Outcome	Stakeholders	Key objective	Delivery Mechanism	Timing	Risks& Mitigation	Responsibilities	Resource Needs	Impact Indicators

The templates below will be used when mapping is taking place of 'Actual' impacts versus 'Expected' impacts based on the baseline data and clients' requirements. This will give a clear image of which impacts have been fully achieved and which needs more time, and hence will be assessed in later phase of the project. The table below represents a template that measures outcomes of low complexity or short-term span.

Table 1: Low Complexity Template

Pilot:	Date:	
	Lower Complexity / Short Time Span	
	Expected Impact/outcome	Actual impact/outcome
Technological	-	-
	-	-
	-	-
	-	-
Social	-	-
	-	-
	-	-
	-	-
Cultural	-	-
	-	-
	-	-
	-	-
Economic	-	-
	-	-
	-	-

	-	-

The table below represents a template that measures outcomes of higher complexity or long-term span.

Table 5: High Complexity Template

Pilot:		Date:
	Higher Complexity / Long Time Span	
	Expected Impact/Outcome	Actual Impact/Outcome
Technological	-	-
	-	-
	-	-
	-	-
Social	-	-
	-	-
	-	-
	-	-
Cultural	-	-
	-	-
	-	-
	-	-
Economic	-	-
	-	-
	-	-
	-	-
etc…		

Recording – Pre- and Post-interventions Templates

The templates in the two tables below are proposed to record the situation before and after the use of the IoT technology. Each client will fill a separate form.

Table 6: Pre-Intervention Form

Pilot	Context	User Group	Test site	Nº & role of stakeholders	Methods	Date	Objectives	Outcomes	Actions to be taken	Re-test date
					e.g. focus groups, interviews		Understand current procedures			

Table 7: Post-Intervention Form

Pilot	Context	User Group	Test site	Nº of users	Method	Date of test	Technology	KPIs	Objectives	Results	Actions to take	Re-test date	Barriers to adoption

3. FRAMEWORK VALIDATION

This section discusses efforts made to ensure the validation of the proposed Impact Assessment Framework. Below, we list the validation tasks performed:

A. Guidance

The framework was informed by the guidance of the G8 Social impact and investment Forum (Impact Taskforce, 2014), REF2014 (REF, 2014), REF2020 (HEFCE, 2017), and Economic and Social Research Council (ESRC, 2017).

B. Comparison

The framework was compared to similar impact assessment frameworks from selected research projects such as:

a) AMITRAN Project, funded by the European Commission (Mahmod, Jonkers, Klunder, Benz, & Winder, 2014)

b) Investment Facility Project (IF), funded by the European Investment Bank (EIB, 2005)

c) Vitae Impact Framework (Bromley & Metcalfe, 2012)

CONCLUSION

Successful IoT projects are committed to the effective assessment of the outcome of their innovation and technologies, as part of their mission for evidence-based impacts. Assessment is an important tool for examining the relevance, performance, efficiency and impact of IoT technologies in relation to its stated objectives and wider strategic goals.

This paper proposes a framework for the impact assessment of IoT innovation activities. The framework was informed by well-established practices and guidelines from prominent bodies such as the G8 Social impact and investment Forum, REF2014, REF2020, and RCUK. The structure of the framework was informed by 'Theory of Change', and the framework dimensions represented impact planning, data collection and validation, implementation and refinement of the framework. Time requirements, issues of contribution, and reporting were covered by the framework. Collaboration and engagement with the stakeholders was a key element of the framework.

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