University Alliance
Doctoral Training Alliance

DTA3/COFUND Programme Research Project Proforma

Page 1 – General Information

Project Code	TSEN04
Partner University	Teesside University
Faculty/School/Department/Research Centres	School of Science, Engineering and Design, Engineering Department
First supervisor	Dr Sergio Rodriguez https://research.tees.ac.uk/en/persons/sergio-rodriguez
Second supervisor	Dr Vladimir Vukovic https://research.tees.ac.uk/en/persons/vladimir-vukovic
Third supervisor	Dr Farzad Rahimian https://research.tees.ac.uk/en/persons/farzad-rahimian
Fourth supervisor	Prof Nashwan Dawood **https://research.tees.ac.uk/en/persons/nashwan-dawood**
External/industrial supervisor	Dr Bimal Kumar, University of Northumbria at Newcastle, UK
Which of the supervisors listed above is an early-career-researcher (within 5 years of completing their doctoral degree)	Dr Sergio Rodriguez (PhD 2016)
Contact details for project for informal applicant queries Email address	s.rodriguez@tees.ac.uk
DTA Programme	DTA Energy
Project title	Unified City Information Modelling. A challenge to resilient and efficient societies

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Page 2 – Project Description

Scientific Excellence (500 words)	The concept of "built environment" comprises both natural and artificial assets built by humans: cities, infrastructures and public spaces. Highly pervaded with various types of sensors, such environment generates loads of data. It can be viewed as a taxonomic subdivision between four overlapping domains: Building Information Modelling (BIM), Geospatial Information Systems (GIS), Infrastructure, and Product Lifecycle Management (PLM). Thus, Big Data applications in this field should consider a modular view, going from a component- to nation-scale (as the levels of detail envisioned for this project: building, neighbourhood, city and region). City Information Modelling (CIM) is being understood[1,2] as the base for most Smart-City frameworks and designs[3]. This is already being carried out a piecemeal development with the help of smart sensors or IoT for traffic regulation, parking etc. Like the city of Rijeka, cities are adopting a Balanced Score Card (BSC) to develop and align their strategies[4]. This gives a clear system for strategy definition & dissemination, feedback and alignment. Existing commercial trials include: ET City Brain by Alibaba[5], Car2X technology demonstration by Volkswagen and Siemens[6], SAP HANA, Leonardo, Vehicles Network and Cloud platforms[7], IBM Intelligent

[1] Khemlani, "City Information Modeling: AECbytes Feature."
[2] Fredericque and Lapierre, "3D City GIS – A Major Step towards Sustainable Infrastructure. A Bentley White Paper.," 2013.
[3] Trimble Inc., "Next in BIM: City Information Modeling (CIM)."
[4] Mauher and Obersnel, "Intelligent City Balanced Scorecards for the City of Rijeka."
[5] Alibaba Cloud ET City Brain, Cities Empowered to Think, https://www.alibabacloud.com/et/city, 2019
[6] Volkswagen and Siemens make crossroads safer, https://www.volkswagenag.com/en/news/2018/10/volkswagen-and-siemens-make-crossroads-safer.html, 2018
[7] Smart Cities World Forum, http://www.smartcitiesworldforums.com/news/smart-cities-middle-east/5g-iot-me/802-sap-announces-partnerships-designed-to-propel-smart-city-innovation-in-me, 2019

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	Operations Center for Emergency Management[8], Atos MyCity[9]. Open source and freeware platforms include Sofia 2, FIWARE, OpeNRJ, DG Logik, AQUICN. Barriers still impede making the process available for end-users. Neither it integrates the much-needed BIM processes and models into the Geographic Information System (GIS), e.g. CityGML, and vice versa so that the GIS informs the BIM model Spatio-temporal data models deal with capturing information characterized by both spatial and temporal semantics. Such integration would open an opportunity to create a Unified Building Model (UBM)[10] with adequate granularity to form the basis for predictive modelling and analysis. Development of the exchange protocols and XML schema aside, existing challenges lie in aligning the various specialized disciplinary silos. Departments and governing bodies need to work collaboratively to create, maintain and manage the integrated data with the key strategies in mind. The Thesis will develop a framework used to present a data model in Unified Modeling Language (UML) focusing on spatio-temporal events where characteristics are categorized as thematic, spatial and temporal attributes, able to seamlessly comprehend the layers attained to buildings, to cities, and sensors in real time.
Aim (400 words) You may wish to include headings – Hypothesis, Methodology and Innovations	The Aim is to develop an implementation methodology and knowledge framework to maintain the integrity of the semantic model across platforms and ensure processes are developed and implemented successfully to achieve the strategic targets. The research will work towards identifying a standardized framework and support processes for information exchange, based on the BIM implementation framework. It will address the size of individual organizations and government bodies, core domain and complexity,

[8] IBM, Intelligent Operations Center for Emergency Management Overview, https://www.ibm.com/us-en/marketplace/emergency-management, 2019
[9] Atos, MyCity https://atos.net/en/industries/local-government-cities/mycity, 2019
[10] Karan, Irizarry, and Haymaker, "BIM and GIS Integration and Interoperability Based on Semantic Web Technology."

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	along with measurable assessments aligned to the strategy. The goal is to help stakeholder engagement and on-boarding to aid strategy awareness, adoption and alignment, as well as knowledge creation rather than information exchange. Hypotheses: o Process and goal-driven, integrated or unified BIM and city information models offer the appropriate granularity for more accurate predictability than fragmented analysis of individual facility BIM models or current city information models. o Better prediction models are obtained by stakeholder awareness, engagement, on-boarding and feedback. Gamification has a far greater level of success in ensuring engagement and strategic alignment, than other means. o The key challenge of Intelligent Unified City Modelling Implementation is strategically aligned change management. Gamification through AR and VR tools leads to a greater level of success. o Critical KPIs / targets for any developments and design change in the city fabric given today's climatic upheaval is sustainability and resilience. City Information Modelling implementation across all new and existing projects, as well as integration of BIM models, will lend the much-needed agility and iterative ability to municipalities augmented by live data at the relevant and required granularity and scale. This would subsequently lower the cost of assessing the impact of proposals, designs and development.

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Figure 1 Four step methodology

Objectives:

1. Develop the framework which helps the city transform to intelligent and unified city information modelling paradigm rather than a physical or digital graphical and/or information record;
2. Align city development strategy using simulation and prototyping;
3. Develop tested tools to aid the on-boarding of the various departments, stakeholders;
4. Enable correct and timely feedback and knowledge contribution.

Methodology

Step 1: Adoption of the Delphi method to facilitate optimised process formulation along the supporting standards[11]. The conducted analysis would be qualitative as well as quantitative. The XML exchange formats, enabling the integration of BIM and CIM into a UBM will require information exchange process and standard definition and execution. The vast number of stakeholders in the various project teams work on varying model authoring and federation software, the complexity levels, and global teams, subject to individual subjectivity, competence and understanding. This is the key challenge the research aims to address.

Step 2: Developing the analysis framework with the help of machine learning data analytics to provide accurate forecasts and enable the Unified City Modelling implementation to strategically align design for resilience. Using SMR Tools, in case of a disaster, would allow optimal utilization of the city infrastructure and optimized resource

[11] Chen, "A Strategic Decision Making Framework for Organisational BIM Implementation."

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	management through scenario-based planning simulation and smart alerting notifications[12,13]. Step 3: Utilizing City design parameters and predictive analytical framework to create algorithms for resilience mapping using City Information Modelling, VR & AR gamification for strategy alignment and sensors to collect and record real-time data. Step 4: Validation. This leg of the research will assess the success of implementation framework and utilising strong industry and government alliances in data collection and post implementation.
Strategic Relevance (300 words)	The proposed process re-engineering and goal oriented collaborative approach, including digital transformation and change management framework implementation, are expected to leverage CIM for parametric analysis e.g. Modelling Interdependent Smart City Infrastructure[14], and analysis based on indicators suggested by the ISO/DIS 37120 "Sustainable development and resilience of communities - Indicators for city services and quality of life". The task will contribute to the standards and frameworks for BIM implementation, which are still emerging[15]. Public and proprietary standards used for file import/export, as well as for communication between services are being developed with no single methodology. The interoperability[16] schemas are being developed for BIM and CIM platforms[17]. Because of the diversity and complexity of domain knowledge across BIM and GIS, however, these syntactic approaches are still not capable of completely sharing semantic information that is unique in each system, which will be achieved within the proposed

[12] *ISO 22395:2018(En), Security and Resilience — Community Resilience — Guidelines for Supporting Vulnerable Persons in an Emergency*.
[13] *ISO 22327:2018(En), Security and Resilience — Emergency Management — Guidelines for Implementation of a Community-Based Landslide Early Warning System*.
[14] Schoonenberg, Khayal, and Farid, *A Hetero-Functional Graph Theory for Modeling Interdependent Smart City Infrastructure*.
[15] Chen, "A Strategic Decision Making Framework for Organisational BIM Implementation."
[16] Fredericque and Lapierre, "3D City GIS – A Major Step towards Sustainable Infrastructure. A Bentley White Paper.," 2013.
[17] Karan, Irizarry, and Haymaker, "BIM and GIS Integration and Interoperability Based on Semantic Web Technology."

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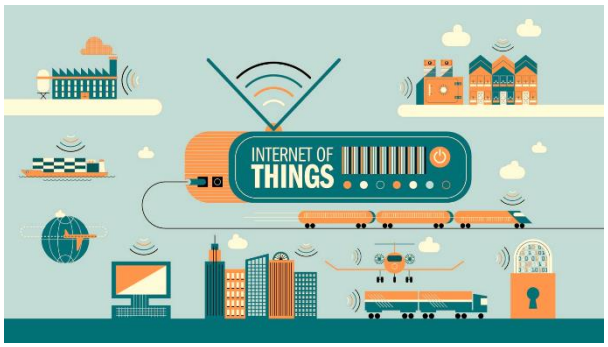
	work. Applications include e.g. traffic rerouting in case of scheduled maintenance or accidents, traffic jams etc[18].  *Figure 2 Internet of Things (quantified data informing the various transit systems)* IoT (quantitative data) presented along with the qualitative inputs collected via gamification based on VR and AR, will help the decision-making process[19] and truly bring the last mile connectivity to the people and their representatives[20]. This would aid collaborative knowledge development, business resilience[21] and opportunities for knowledge assimilation and strategy alignment to make better informed decision-making, based on pre-simulated scenarios.
Interdisciplinarity and fit with DTA3	*"The challenges that cities face, and will continue to face in the future, are complex and multi-sectorial. They are also very specific – no two cities are the same."*[22] Interdisciplinary nature of this research is inevitable. Evident from the aim to address a variety of potential stakeholders and requiring inputs from fields of knowledge and application from psychological analysis of stakeholder engagement and optimization, sustainable city design, parametric modelling and resilience, to strategy or policy development. Its fit within the DTA Energy programme is mostly related to the smart city design targets: optimised design, operations, sustainability and resilience; tangible and quantifiable benefits within the domain of energy studies based on ISO 17742 Energy efficiency and savings calculation for countries, regions and cities.

[18] "Smart City Standards 101 -- Connectivity and IoT — Smart Cincy."
[19] Cagáňová et al., "The Analysis of the Slovak Citizens' Awareness about the Smart City Concept."
[20] Das and Das, "Thinking Smart: Residential Green Retrofit, India."
[21] *ISO 22313:2012 - Societal Security -- Business Continuity Management Systems -- Guidance.*
[22] "ISO Strategic Advisory Group on Smart Cities-Demand-Side Survey."

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Industrial Relevance (300 words) Detail external placement opportunities or collaborations available as part of the project	A number of large industry players aim to take a share of the emerging digital city markets. Previously mentioned platforms by Alibaba, Siemens, SAP, IBM and Atos are only some of the existing solutions available on the market. Existing and past research collaborations Teesside University had with Siemens, IBM and Atos open possibilities for placement and continued collaboration within the remits of the proposed DTA3 research. Furthermore, the topic is relevant for the developing countries. Existing contacts of the supervisory team with relevant industry in low-mid income countries open opportunities for placement in such emerging sectors of the economy.
Economic and Societal Impact (300 words)	By definition *"A 'Smart City' is one that dramatically increases the pace at which it improves its social, economic and environmental (sustainability) outcomes, responding to challenges such as climate change, rapid population growth, and political and economic instability by fundamentally improving how it engages society, how it applies collaborative leadership methods, how it works across disciplines and city systems, and how it uses data information and modern technologies in order to transform services and quality of life for those in and involved with the city (residents, businesses, visitors), now and for the foreseeable future, without unfair disadvantage of others or degradation of the natural environment."*[24] The research looks to taking a holistic approach to make the supporting framework for Smart cities better informed and sound in its offering from possibility of real-time informed decision-making and setting targets to be technologically current in stakeholder engagement.

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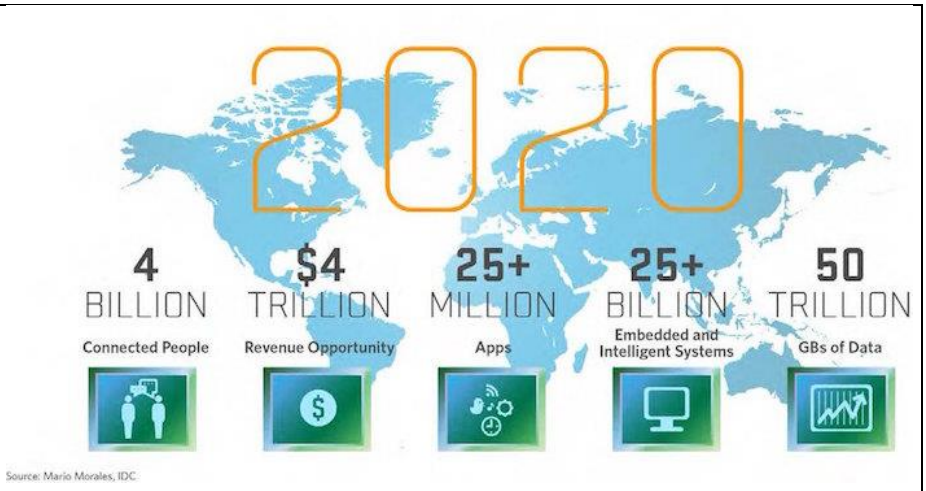

Figure 3 Some of the smart city opportunities

The business opportunities open up with knowledge creation and data availability in smart cities, as presented in Figure 2. The resulting total revenue opportunity amounts to approximately $4 trillion by 2020, connecting 4 billion people via more than 25 billion smart systems.

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Page 3 – Admission Requirements

Specific Admission Requirements Detail any subject specific degree qualifications or disciplines, relevant skills, experience	Master degree in architectural engineering, mechanical engineering, electrical engineering, computer science or related area, with a GPA above 60%.
Minimum IELTS score	6.5

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