Cross-sectoral Process Modelling for Smart City Development

Journal:	*Business Process Management Journal*
Manuscript ID	BPMJ-05-2021-0333.R1
Manuscript Type:	Original Article
Keywords:	business process management, Business process redesign, Systems integration, smart city development, Process modelling, city process change

Cross-sectoral Process Modelling for Smart City Development

Abstract

Purpose- Integration of city systems is needed to provide flexibility, agility, and access to real-time information for the creation and delivery of efficient services in a smart and sustainable city. Consequently, City Process Modelling (CPMo) becomes an essential element of connecting various city sectors. However, to date, there has been limited research on the requirements of an ideal CPMo approach and the usefulness of available Business Process Modelling (BPMo) approaches. This research develops a framework for CPMo to guide smart city developers when modelling city processes.

Design/Methodology/Approach- Data from literature analysis was gathered to derive capabilities of existing BPMo techniques. Then, semi-structured interviews were conducted to thematically and qualitatively explore the requirements, challenges, and success factors of CPMo.

Findings- The interview findings offered 17 requirements to be addressed by a CPMo approach, along with several challenges and success factors to be considered when implementing CPMo approaches. Then, the paper presents the results of mapping these requirements against 12 existing BPMo capabilities, identified from the literature, concluding that a significant number of requirements (which are mainly related to inputs and visualisation) have been left unfulfilled by existing BPMo approaches. Hence, developing an innovative CPMo approach is necessary to address the components of unfulfilled requirements.

Originality/value- The innovative framework presented in this paper justifies the CPMo requirements, which are unexplored in existing SCD frameworks. Moreover, it will act as a guide for smart city developers, to model cross-sectoral city processes, helping them progress their SCD road map and make their cities smart.

Keywords: City process modelling, Business process modelling, smart cities, smart city development, Business process management

Article Type: Research paper

1. Introduction

Smart City Development (SCD) was introduced to resolve urbanisation problems, such as overpopulation, overuse of resources, environmental problems, economic and social issues (Javidroozi et al., 2019; Jamous and Hart, 2020). With the aim to improve the citizens' lives by streamlining the service delivery, globally the city authorities are actively investing in technology-led initiatives aimed at transforming the cities into smart cities (Girardi and Temporelli, 2017; Komninos and Mora; 2018). On the other hand, a city is regarded as an integrated system, consisting of many sub-systems, such as healthcare, transport, education, energy, housing, as well as several management authorities and agencies that run these systems (Javidroozi et al., 2015; Pierce et al., 2017). The systems integration concept in SCD has also been further explored in the smart city initiatives framework, where a smart city has been envisioned as an integrative framework of components, such as management and organisation, technology, governance, policy, people and communities, economy, built infrastructure and the natural environment (Chourabi et al., 2012). Thus, city systems integration is a necessity for SCD, resulting the integration of people, institutions, and technology-mediated services that is similar to Enterprise Systems Integration (ESI) in the private sector, where Business Process Change (BPC) enables enterprises to integrate disjointed information systems and achieve operational efficiency (Motwani et al., 2002; Nam and Pardo, 2011; Harmon, 2014). This indicates that ESI and SCD have similar aims and objectives from systems integration perspectives, so that smart city can be considered as a large-scale, complex, and integrated enterprise, in order to utilise the learnings from enterprises for addressing the relevant SCD challenges. Consequently, BPC also becomes an essential part of city systems integration in SCD, in order to offer efficient services to citizens in real-time (Javidroozi et al., 2014 and 2019).

BPC is a complex task, which encompasses several steps and challenges to be considered and addressed. The challenges, such as inter-dependencies, standardisation, flexibility, agility, governance, and interoperability of business processes are some examples that need to be carefully measured and sustained during BPC and it cannot be achieved without the use of methods that have been developed to facilitate the process of BPC, depending on the type and scale of the change. Business Process Modelling (BPMo) is one the methods, which plays a central role to understand the existing processes, identify the issues, address the challenges, justify the necessity of change, and most importantly to redesign the processes and align them with the purpose of systems integration (Javidroozi et al., 2019). In addition, choosing an appropriate BPMo tool supports the efficiency of BPC. Moreover, the visualisation offered by an appropriate BPMo tool helps comprehend existing processes and reduce the wasteful activities within a process, so that provides more efficiency for business processes (Slack et al., 2009; Xu, 2011) and offers a basis to the orchestration of technological enablers along business processes (Bandara et al., 2021).

The concept of BPMo and its various tools, techniques, and languages have been extensively discussed in the ESI context, with respect to the methodologies, guidelines, and design of the frameworks and techniques to facilitate BPC and addressing related challenges (Harmon and Wolf, 2011; Bhaskar, 2018). However, very limited research has been carried out on the use of appropriate process modelling approaches for the purpose of SCD (referred to as City Process Modelling (CPMo) in this research) (Forliano et al., 2020), while the critical success factors and challenges of BPC in ESI and SCD contexts are similar (Javidroozi et al., 2019) and as such, it can be concluded that CPMo will help redesigning cross-sectoral city processes and addressing the challenges involved. Nevertheless, no recommendations have been made for a specific process modelling tool for the purpose of SCD, while it is crucial for city authorities to effectively innovate their business processes in this systemic context towards becoming smart (Forliano et al., 2020). However, there is a wider discussion about different frameworks to transform a city into a smart city based on various dimensions of technology application and people management. For example, the integration landscape model proposed by Jamous and Hart

(2019), which incorporates multiple smart cities' frameworks, as well as integration approaches of enterprises to support the orchestration of smart city services. Although the model addresses the integration problem of smart cities' services with a combination of multiple approaches, it significantly lacks the discussion regarding process modelling, which is needed for the proposed framework to be viable. Even the Smart City Framework (BSI, 2015), which is a generic framework for guiding the city leaders in realising the smart city vision in collaboration with all key stakeholders and follows a citizen-centric approach, does not provide a clear direction regarding city systems integration and its components including BPC and CPMo.

Hence, it is evident that very limited to none academic research have discussed CPMo and the selection of an approach to model the cross-sectoral city processes for SCD. As a result, a comprehensive research including data gathering from primary sources is necessary to close the gap in the literature and to answer the following research question: "what are the characteristics of an appropriate approach for city process modelling?"

To answer the research question, the characteristics of an appropriate CPMo approach should be discussed with SCD experts and who are involved with changing city processes for the purpose of SCD. It should also be realised that if the existing resources are able to offer those required characteristics. Then, the characteristics of CPMo from various dimensions should be presented to guide smart city process modellers. Therefore, this research will review the existing process modelling approaches, utilised by various tools, techniques, and languages in various contexts such as ESI, and aims at developing a framework for modelling city processes that would act as a basis for further developments of process modelling approaches in the SCD context. The following objectives will be addressed to achieve the aim of this research, hence answering the research question:

- Objective 1: To explore existing BPMo tools, techniques, and languages and critically review them for the purpose of SCD by identification of their capabilities in the SCD context;
- Objective 2: To identify the requirements and expectations for modelling cross-sectoral city processes, as well as possible challenges, and critical success factors associated with the modelling, through semi-structured interviews;
- Objective 3: To map the existing BPMo capabilities against the CPMo requirements or expectations identified in the previous objectives and to discuss if the requirements of CPMo for SCD can be fulfilled by a single, or a combination of already existing BPMo tools/techniques/languages;
- Objective 4: To develop an innovative framework for CPMo to guide future development of CPMo tools.

The first objective will help to understand the competences available within the ESI context. The second objective provides information regarding what is required for modelling city processes. Next, the results of these two objectives will be compared to realise if the existing competences from ESI are sufficient for CPMo? Then, all the findings will be drown together to present the characteristics of a CPMo approach.

Accordingly, the next section will analyse the existing literature regarding process modelling in ESI and SCD contexts. The research methodology has been explained in section 3, outlining how the objectives of the research are achieved. Next, the research findings will be presented in section 4. In section 5, a discussion of the results will be offered and the CPMo framework will be developed and presented. Section 6 concludes the research, its outcomes, and contributions.

2. Theoretical background

The concept of smart city has been explained by earlier researchers and smart city experts, so that many definitions have been offered in various aspects of the city, such as technology, people, environment, process, economy, services and so forth. These definitions are mainly provided based on the requirements of a particular project or the researchers' interest. For example, Schaffers et al. (2012) rely on technological innovations and discuss that smart city improves inhabitants' quality of life by utilising IT solutions. Nam & Pardo (2011) emphasised "process" as the most important factor in SCD. Townsend (2013) mainly focuses on "people" as a central element of SCD.

Nevertheless, although most of the earlier smart city research projects are towards enhancing liveability and sustainability of the future cities, they have been mainly defined smart city from the technological solutions viewpoint without discussing other aspects, especially the organisational fields. Moreover, they are often concentrated on a single city sub-system, lacking a cross-sectoral vision for transforming a city as a whole (Pierce et al., 2017).

As discussed previously, since city is a complex system of systems and city systems integration is a necessity for SCD, while this study acknowledges the crucial role of technology infrastructure (e.g. Internet of Things (IoT)) as an integration enabler (Scuotto et al., 2016), it utilises the smart city definition provided by Javidroozi et al. (2019), which is mainly focused on cross-sectoral city systems integration for developing a smart city, as a complex and integrated system of systems. Accordingly, since the existing city processes may not allow such a transformation, using an appropriate process modelling approach for changing cross-sectoral city processes is essential to provide integrated and smart services for citizens in real time. In the light of this, by considering a city as an integrated enterprise, learnings from ESI will be useful to transform the cross-sectoral city process (Javidroozi et al., 2014).

To change business processes in ESI there are several approaches , utilised by various tools, techniques, and modelling languages; most popular ones being Flowcharts, Data Flow Diagrams (DFD's), Integrated Definition for Function Modelling (IDEF), Role Activity diagram (RAD), Petri Nets, Business Process Model and Notation (BPMN), Unified Modelling Language (UML), and so on (Harmon and Wolf, 2011). The selection of an appropriate approach is based on the project requirements. Since a city is a complex system of sub-systems with cross-sectoral processes supported by a regulatory framework (Gascó-Hernandez, 2018), to achieve BPC at the city level, it will be necessary to assess these approach and explore their capabilities to determine if they match the requirements of cross-sectoral CPMo. In a survey conducted by Harmon and Wolf (2011), BPMN2.0 was listed to be the tool of choice for process redesign or improvement in enterprises across various departments. However, no such research exists for the selection of BPMo approach to act for the purpose of CPMo. As explained by (Anthopoulos and Giannakidis, 2017), in some cities such as Trikala in Greece, a process was modelled by connecting the required tasks and their components. The authors believe that such modelling approach can be considered as a guide for other business processes. However, based on the argument of this paper, there should be a proper guidance to help process modellers utilise a process modelling approach for making the city processes smarter.

There are several comparisons and evaluation frameworks for selection of BPMo tool/technique/language in ESI context and evaluation approaches to assist decision-making (Medoh and Telukdarie, 2017). The current literature on BPMo application in SCD context focuses on the BPMo capabilities and suitability in a specific area of implementation. Two examples are the comparison of DFD with UML with respect to requirement gathering in healthcare research (DeLusignan et al., 2012), and suitability of BPMN for the planned modelling and imaging of clinical pathways owing to its technical ability to model complex processes and decision-making abilities (Scheuerlein et al., 2012). The first one facilitated more effective stakeholder engagement with clinical research and trials, due to the use cases developed with UML being visual in nature. It also helped to consolidate data repositories, which were in various formats and disparate locations across multiple healthcare settings. In the second comparison, the technical capabilities of BPMN with respect to the ease of graphical imaging of complex processes, integration of checklists, guidelines, and medical documents proved effective in developing the clinical pathways (Scheuerlein et al., 2012).

Some researchers (e.g. Mendling et al., 2010) have proposed setting guidelines for addressing the quality of BPMo approaches with the goal of reducing the error probability of the output by reducing extensive multiple branching. These guidelines use as few elements in the model as possible, minimise the routing paths per element to control the number of input and outputs, use one start and one end event, build the model as structured as possible, avoid 'OR' routing, use verb-object activity labels, and decompose the model, if it has more than 50 elements. These will help reduce the error probability by 50%. However, these guidelines are unsuitable for SCD as in a city; different departments and stakeholders have different requirements and expectations in relation to a SCD project and as such, the requirements are very complex by nature.

Chen and Wang (2017) have also discussed using process modelling techniques (e.g. BPMN) and languages (e.g. eXtensible Mark-up Language (XML)) to develop processes for connecting IoT devices in SCD projects, but their research lacks discussion about its suitability for cross-sectoral city systems integration. In the integration of the triple helix framework with the Analytic Network Process (Lombardi at al., 2012) to model, cluster, and measure the performance of smart cities and cyber-physical systems (Lom and Pribyl, 2020), the smart city is compared with the environment and the systems within the city (energy, transport, buildings). In this comparison, it has been evident that the standalone systems interact only with their environment in traditional cities. However, smart city requires the systems to be interconnected with each other, so that the issue of interoperability becomes a major challenge that needs to be considered. Hence, there is a significant lack of discussion on the cross-sectoral process modelling or systems integration aspect of SCD.

Furthermore, "data" as the core component of building a smart city has been discussed by several authors and as such, several frameworks have been proposed around this concept (e.g. Osman, 2019). However, as previously discussed, nearly all frameworks lack a comprehensive consideration of cross-sectoral process modelling. For instance, Osman's (2019) framework, which follows a layered and data driven design approach based on real-time and historical data analytics, focuses on the data element of SCD, not the process modelling element, which is needed to integrate the city systems, thus making it unsuitable for CPMo. This framework is based on the standardisation of data acquisition, access, and iterative/sequential data processing. Another example in this context is the work carried out by Ibrahim et al. (2018) regarding the smart city roadmaps to achieve a city's vision of sustainability. The city's readiness to transform with ICT and non-ICT infrastructure has been addressed in this framework, which may be useful for the city planners to assess the infrastructure capabilities of their own city. Likewise, the framework proposed by Budhiputra and Putra (2016) is built on the BPR approach in four stages. At every stage, the author proposes the requirement of specific tools to assess the current business processes and to identify the problems in the existing processes with the end vision of achieving business process standardisation, but the capabilities of these tools or criteria for selection have not been discussed. Moreover, the smart city framework in PAS 181: 2015 (BSI, 2015) provides guidance for decision-makers in smart cities and communities (from the public, private and voluntary sectors) to develop and deliver smart city strategies that can transform their cities' ability to meet future challenges. The framework is incumbent upon the stakeholders involved in the smart city projects to explore the requirements and challenges of SCD through extensive requirement analysis, and it does not provide a singular set of guidelines or a systematic approach for individual city authorities for changing city processes. Hence, it does not provide useful information regarding CPMo. Another example is a smart asset alignment framework (Heaton and Parlikad, 2019), which is built on the Smart City Framework (BSI, 2015), where infrastructure assets are classified as per the functional outputs with the purpose of aligning the citizen's requirements with the city services. However, the framework does not address the integration aspect of the city's services, which is essential to remove siloed interactions of citizens with individual city services. Using IoT and a data-driven approach, Westraadt and Calitz (2020) have also designed smart city planning frameworks, which applies data generated by Integrated City Management Platforms (ICMPs) to identify cross-sectoral synergies and interdependencies. This framework may be useful to develop point solutions for targeted problem areas, but the primary focus of this framework being the data element, due to which it does not serve the purpose of SCD from a systems integration perspective. Next example is the Smart City Initiatives Design (SCID) Framework (Ojo et al., 2015), which is a top-level generic model of a smart city with no in-depth analysis of BPC or CPMo elements to realise the vision of perceived outputs. Finally, the representation of a higher-level conceptually integrated smart city in Jamous and Hart's (2019) framework offers a high degree of crosslinking, ensuring better process control. Although this framework represents an ideal integrated smart city, the research lacks the discussion about the methodology with respect to process change to achieve this vision.

These findings confirm the fact that there is a significant lack of literature on the discussion about process modelling concept for SCD. As a result, no singular BPMo approach or a combination of them have been proposed for modelling of city processes for SCD. Hence, this research will utilise a combination of secondary and primary research to analyse the existing BPMo tools, techniques, and languages used in the ESI context and develop a framework as a guide towards developing an appropriate CPMo approach.

3. Methodology

In order to address the research objectives outlined previously, secondary data was collected to identify the capabilities of existing BPMo tools, techniques, and languages in the context of SCD. Primary data collection via semi-structured interviews was done to find the requirements of cross-sectoral CPMo, the challenges involved and Critical Success Factors (CSFs) to address the challenges.

To explore existing BPMo tools, techniques, and languages and critically review them for the purpose of SCD by identifying their capabilities for the SCD context (Objective-1), literature analysis was used. Data was collected from academic resources as well as the documents published by smart city solutions providers. Major databases such as Scopus, Science Direct, and ProQuest were used. Birmingham City University's Library search engine and Google Scholar were also applied to locate the data sources. Literature published between 2010 to 2020, peer-reviewed journals and conference papers or publications on studies conducted on the process modelling aspect of SCD projects, smart city case studies, where cross-sectoral process improvement or modification is the focus of the research were qualitatively analysed to find the ideal BPMo capabilities in SCD context.

The purpose of the primary research was to fulfil objective-2, which was to identify the requirements and expectations, as well as the challenges and CSFs for modelling cross-sectoral city processes. Nevertheless, the interview started by asking questions regarding the interviewees'' experience of using any modelling tool/technique/language for designing city processes.

The focus of primary data collection through structured interviews (Knox and Burkard, 2009) was to generate empirical data on the process modelling aspect of SCD projects. Participants for the research were identified based on individual involvement in smart city projects, business process analysis, city council governance, academic research on smart cities, and planning and coordination of smart city projects. The inclusion criteria for the selection of research participants were as follows:

- Having more than five years of experience in SCD;
- Having been directly involved with the development of a smart city, especially in BPC and CPMo projects; and
- Fitting in project management, city council governance, smart city consultation, implementation, or smart city solutions architect role categories.

These participants were then interviewed remotely via Microsoft Teams or Zoom.

Also, to ascertain generalisation of research participants, they were chosen from different parts of the world i.e., UK, EU, India, USA, and the South East. Hence, a global non-probability and purposive sampling was assured (Cornesse et al., 2020) to select interviewees based on their job affiliation and ability to provide relevant information from various smart city projects worldwide. City administrations across the world are at different levels of technical expertise and social dynamics, and such the expectations from a smart city varies greatly across the various levels of stakeholders involved in this transformation process. As a result, due to the exploratory nature of this research this sampling approach helped to capture varying experts' views on CPMo requirements from different levels of expertise and from various parts of the world. Accordingly, the following criteria were followed, when the sampling approach was implemented:

- Involved with the smart city projects, especially city process change phases;
- Fit in project management or implementation role;
- Experience:
  - Minimum of two years;
  - Gained from various levels of smart city readiness as observed from the literature.

Related to changing existing city processes, thirteen interviews were conducted as part of this process and Table-1 highlights the city/country and organisation/company of all the interviewees.

Table-1: Some information about interviewees

Interviewees	Smart city experiences	Total number of city councils/organisations per interviewee
Interviewee-1	Warwick, Walsall, Birmingham, Wolverhampton (England); TMS Consultancies	5
Interviewee-2	Birmingham (England); Highways England	2
Interviewee-3	Manchester (England)	1
Interviewee-4	Bristol (England), Rome (Italy), Barcelona (Spain), Munich (Germany), Beijing (China), Moscow (Russia), Buenos Aires (Argentina), Sydney (Australia), and New York (USA); Smart cities World and UK 5G	11
Interviewee-5	New Delhi, Bhopal, and Mumbai (India), Dubai (UAE)	4
Interviewee-6	Jakarta (Indonesia)	1
Interviewee-7	Kuala Lumpur (Malaysia)	5
Interviewee-8	Frankfurt (Germany) and New York (USA); Gartner Consultancy	2
Interviewee-9	Birmingham (England)	1
Interviewee-10	Madrid and Barcelona (Spain); AXPE Consulting	3
Interviewee-11	Jakarta (Indonesia); Qlue Smart City	2
Interviewee-12	Birmingham (England)	1
Interviewee-13	Trento (Italy); EURAC Research	2

Every interview was conducted for a minimum of 30 minutes. An invitation letter with a research information sheet and consent form was sent to the interviewees before the interview meetings could take place. In addition, permission to record the interview was obtained in advance. The interviews were audio-recorded and notes were taken to be used for qualitative data analysis afterward.

The focus of the interview questions was to gather information on the followings datasets:

1) existing approaches used to model the cross-sectoral city processes in the SCD projects and the advantages or disadvantages of these approaches;
2) the requirements and expectations from an ideal CPMo to model the cross-sectoral city processes in the participant's opinion; and
3) the challenges and CSFs asociated with CPMo.

The literature analysis results on findings regarding the BPMo capabilities were analysed and presented in section 4.1. As shown in Figure-1, these findings will be mapped against the interview findings regarding the requirements of CPMo. In addition, the interviewees were also able to provide some information on the current approaches that were being used to plan, control, or monitor progress in the current smart city projects. The findings from this interview section enhanced the literature findings for the first dataset. The second dataset was constructed to identify the requirements of CPMo from the interviewee's perspective to model complex and cross-sectoral city processes (section 4.2.1). Then, the requirements were matched with the capabilities identified in the first dataset to answer the third objective of this research, determining if an existing BPMo on its own or in combination with other tools/techniques/languages can fulfil the requirements for CPMo or an innovative BPMo framework needs to be developed (section 5). The interviewees were also enquired about the challenges and CSFs of CMPo, as the third dataset.

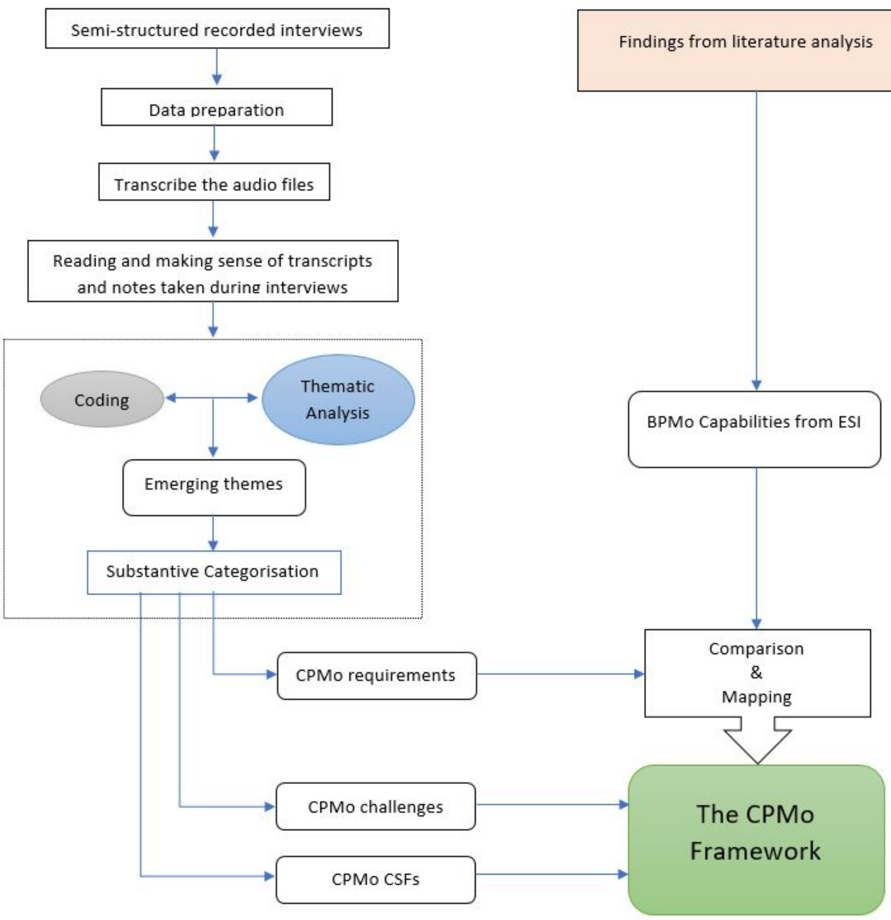

Figure-1: The research analysis design

To analyse the primary data, the interview records were firstly prepared, transcribed, and each transcription was assigned a code instead of interviewees' names to ensure anonymity. In addition, the transcriptions were verified by another colleague for authenticity and data integrity. The notes taken during the interviews were also read and organised to be analysed along with the audio transcriptions. Then, the data was analysed qualitatively to develop themes (Flick, 2013). There was no software used for this purpose and as shown in figure-2, the content was manually analysed. Accordingly, to identify the requirement of CPMo, every material was picked, was carefully read, and the relevant areas of the transcripts/notes were highlighted to excerpt the themes. Then, the themes were substantively categorised to generate a list of topics/categories related to the dataset. Next, similar categories were merged, coded, and utilised to connect related contents. This was carried out for all other material. During the connecting strategy, if a new code were emerged, it was also compared with the existing codes and connected to the related contents. The analysis was repeated to identify CPMo challenges and CSFs to be utilised for further development of the CPMo framework.

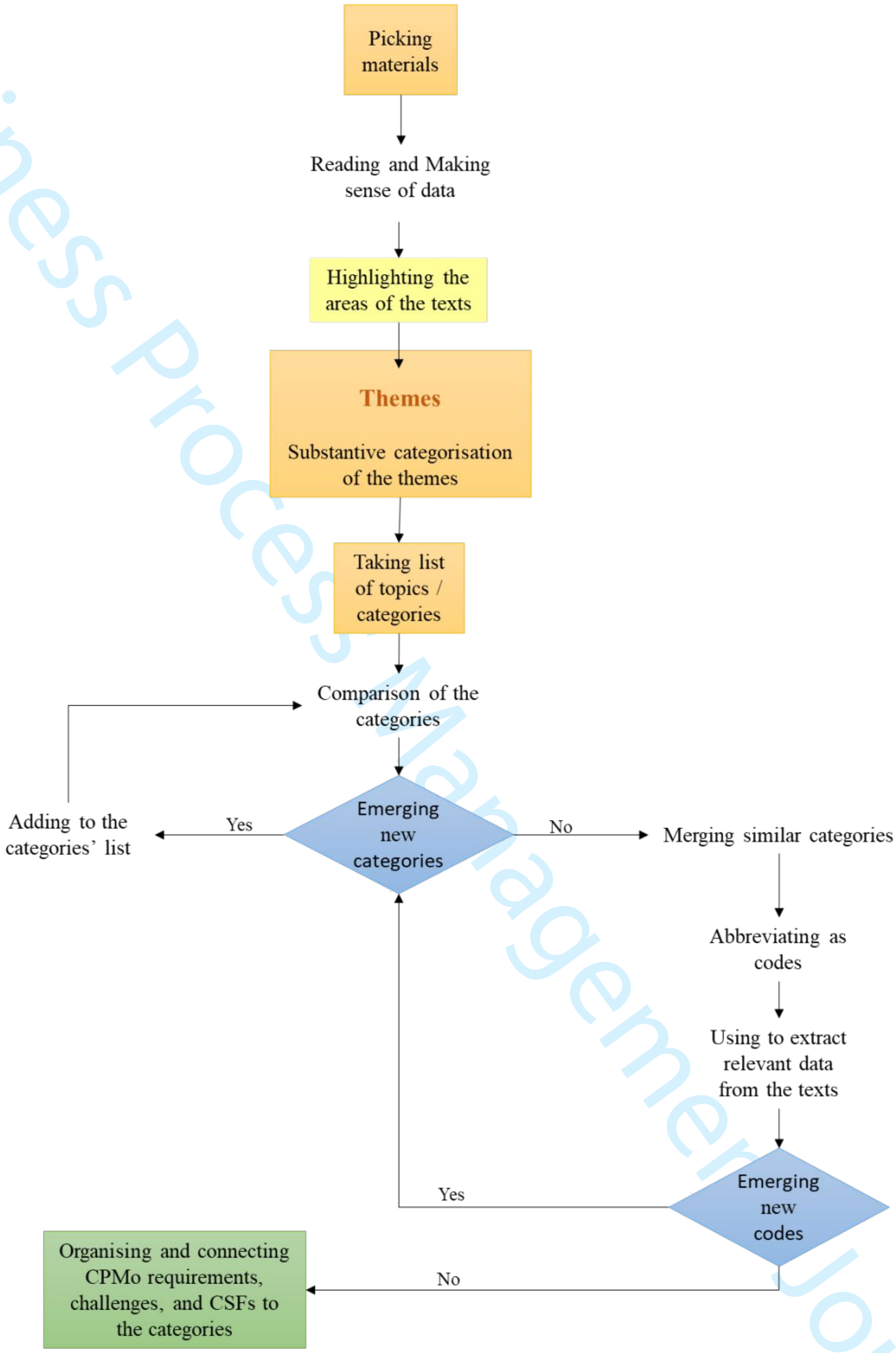

Figure-2: Thematic analysis to identify CPMo requirements, challenges, and success factors

When all three datasets (as shown in Figure-1 and 2) were fully identified and the first dataset was compared with and mapped against the capabilities of existing BPMo approaches in the private sector, the results were discussed and applied to develop the CPMo framework of this research.

4. Research findings

The findings of this research from secondary and primary sources will be presented in the following two section:

4.1 Findings from literature analysis

A smart city is considered as an integrated enterprise, due to the level of similarity in the requirements of systems integration between them. In order to identify the required modelling capabilities of existing BPMo for SCD purposes, it was necessary to research those capabilities in the ESI context by identifying broad level similarities between the two. In a complex enterprise, there are multiple departments, multiple levels of hierarchy, stakeholders, and other complexities, especially in business processes (Momoh et al., 2010; Javidroozi et al., 2014, 2019). In the ESI context, organisations at Capability Maturity Model (CMM) level 3 and 4 have performed BPMo for continuous business improvement and/or organisational re-design for efficiency purposes (CMM level 3 - where processes are organised and redesigned at the enterprise level and CMM level 4 - processes are measured and managed systematically) (Wangenheim et al., 2010; Peldzius et al., 2011). For this reason, it was necessary to identify the capabilities, which are relevant to the ESI perspective as these are very similar in nature and thus would closely relate to the requirements necessary in the SCD perspective. Most cited BPMo tools/techniques/languages that have been used in ESI are as follows:

Flow Charts (Asq, 2019), Integrated Definition for Function Modelling (IDEF), Data flow diagrams, Coloured Petri Nets (CPN) (Mohammadi and Mukhtar, 2012), XML Formats(Coleman, 2013), Role-Activity Diagrams (Subhiyakto and Astuti, 2019), UML Activity Diagrams (Birkmeier et al., 2010), BPL4WS (Business Process Execution Language for Web services) (Jacobsen et al., 2010), Event-Driven Process Chains (EPC) (Karhof et al., 2016), Business Process Modelling Notation (BPMN) (OMG, 2020).

The significant capabilities of these BPMo approaches as discussed in the literature have been presented in Table-2.

Table-2: BPMo capabilities from the literature

BPMo capabilities	References
To create simple and complex (nested) models of processes	Aldin and De Cesare, 2009; Harmon and Wolf, 2011; Scheuerlein et al., 2012; Abdel-Fattah et.al., 2017; Subhiyakto and Astuti, 2019

To define the scope of data requirements	Aldin and De Cesare, 2009; Harmon and Wolf, 2011; Scheuerlein et al., 2012; Medoh and Telukdarie, 2017
To store information about roles, costs and other data associated with activities	Harmon and Wolf, 2011; Scheuerlein et al., 2012; Abdel-Fattah et.al., 2017; Subhiyakto and Astuti, 2019
To perform simulation and analytics support	Aldin and De Cesare, 2009; Harmon and Wolf, 2011; Abdel-Fattah et.al., 2017
To store models and processes in a data repository	Harmon and Wolf, 2011; Scheuerlein et al., 2012
To specify constraints such as deadlines	Harmon and Wolf, 2011
To test the solution including user acceptance testing	Harmon and Wolf, 2011; Scheuerlein et al., 2012
To design training	Harmon and Wolf, 2011; Scheuerlein et al., 2012; Abdel-Fattah et.al., 2017; Medoh and Telukdarie, 2017
Technical capabilities: - Ability to post models to the web - Ability to move models to software code - Ability to print models - Support for a standard notation or modelling language	Aldin and De Cesare, 2009; Harmon and Wolf, 2011; Scheuerlein et al., 2012; Abdel-Fattah et.al., 2017; Medoh and Telukdarie, 2017

In addition to the above, there is no one size BPMo approach fits all types of business processes, so that selection of the most appropriate approach for any context is a significant task that need to be carried out by considering various factors, challenges, and dimensions of that particular context (Lederer et al., 2020; Trauer et al., 2021). In the evaluation of BPMo approaches according to Moody's criteria (Johansson et al., 2012), BPMN scored better over Flowcharts, IDEF, UML, and EPC, based on the following criteria: discriminability, perceptual and cognitive limits, emphasis, cognitive integration, perceptual directness, structure, identification, expressiveness, and simplicity. Although BPMN has most of the capabilities required for process modelling, the following limitations of BPMN in the ESI context must be considered (Smartsheet, 2019):

- Potential mistakes in the modelling elements, due to connectivity or errors in decision making;

- Incorrect modelling can result in the obscurity of process flows, also complex processes require considerable time for modelling, thus resulting in cost increase;
- Effective BPMN implementation requires the stakeholders to possess a higher degree of technical expertise, lack of which can make the communication process daunting and ineffective;
- Representation of complex organisational structures, resources, and strategy can be challenging with projects involving multiple organisations and interconnected processes; and
- Ability to represent complex, interconnected data and information models and functional breakdowns to the lowest levels.

4.2 Findings from primary research

Information about the research participants and the evaluation of data from the primary research has been presented in the methodology section (Table-1). The interviewees were involved in the SCD projects through their own organisation, in the roles of consultants, government officials, or solution providers of smart city solutions. Some of them had worked across multiple organisations, multiple cities, and multiple continents; hence, they could offer a vast experience spanning multiple cities when responding to the interview questions. Accordingly, various data sets from every interviewee with multiple city experience were organised. Thus, it can be concluded that by conducting 13 interviews, CPMo requirements were identified from more than 29 cities in 13 countries, and 8 smart city companies.

The approaches used in SCD projects during stages of initial planning, monitoring, and implementation as identified by the research participants have been listed in Table 3.

Table-3: Approaches used for modelling and changing city processes during SCD projects

Approaches
BPMo techniques, such as Flowcharts, BPMN, MS Visio
Microsoft Project Management tools
Smart city frameworks, such as PAS 181, Smart city benchmark model, Smart city maturity model, Citi scope
Microsoft ICT Tools
ERP Planning tools and packages
Value Chain Diagrams
Soft Systems Methodology, AGILE, Scrum, JIRA

As stated by some interviewees, some advantages with Flowcharts, such as simplicity, ease of addition/removal of processes, as well as some limitations for process mapping were identified (Incomplete visualisation, Inefficient information capture from organisational silos), which are significant from SCD perspective.

In addition, interviewee-9 commented that;

> "BPMN and Visio although have good process mapping capabilities for individual projects, they lack visibility (interconnectedness of processes) between projects, which is a significant limitation."

During the interviews, the usage of some other approaches, such as Microsoft Projects and smart city frameworks were also mentioned by the interviewees, but it was identified that these approaches do not have process modelling capabilities and hence are unsuitable for CPMo purposes (interviewees 5, 7, 11, and 13).

For example, interviewee 5 said:

> "We used the value chain diagram, and then ERP. It can be used for business units, they have to be modified. We also use workflow diagram, we use MS Project also, MS Professional for programme management..."

As discussed by several interviewees (1, 4, 10, 13), it was concluded that the concept of CPMo for SCD is still relatively new. The majority of approaches used in the SCD projects are being used for project management purposes and software development lifecycle projects.

Although it was evident from the discussions that increasingly the respective city councils are exploring the concept of systems integration for SCD, from three interviews, it was also discovered that most of these SCD projects are essentially implemented with the purpose of achieving efficiency gains in a department or to resolve targeted urban problems, such as flood management, waste management or traffic flow management (Interviewees 3, 9, and 12).

4.2.1 CPMo Requirements from Primary Research

The participants were asked to identify the capabilities and requirements of the ideal CPMo for modelling complex cross-sectoral city processes, concerning the city's legislation needs, stakeholder needs, and others. For instance, interview 3 commented:

> "Interoperability on a technical level is important and often there are barriers such as social, legislative etc… I think having some sort of easy to use data repositories, for instance if you are looking at a software tool and it's going to have 10 inputs in terms of datasets, when people still are using spreadsheets and stuff like that and the tech people are putting them into a data repository and what you find is there is not much available that actually allows you at the design level to actually kind of do things in the way I would like to be done really. Yeah so something around process mapping I think and dynamically change inputs and outputs really. If that makes sense."

Interviewee 10 said:

> "action lines, which are the costs, results and which are the benefits, where are the interrelations, and all kinds of connections between objectives, tasks, processes, stakeholders, etc. it will be nice for the project manager to show KPI's in a very visual way to the stakeholders, something more visual and something easier."

A summary of these requirements have been listed in Table-4.

Table-4: Requirements of CPMo for SCD (interview findings)

CPMo Requirements	Interviewees
Ability to model complex processes representing interdependencies between multiple processes, departments & stakeholders	1, 9, 10
Ability to represent interconnectivities among cross-sectoral sub-processes	9, 10
Allow multiple inputs from multiple stakeholders	1, 9, 10
Allow cross-sectoral stakeholder collaboration in process mapping	1, 9, 10
Allows to dynamically change inputs and outputs	3
Allows to link process maps directly to the project requirements	9
Addresses the data related challenges	1, 3, 4, 7, 8, 9
Addresses city's interoperability needs	1, 2, 3, 4, 5, 8, 9, 10, 11, 13
Addresses Security requirement	8
Visualisation of cross-sectoral process flows to resolve potential cross-sectoral legislation conflicts	1, 9, 10
Visualisation of End to end process maps to multiple stakeholders to allow decision making	1, 9, 10, 11, 12
KPI's visualisation and realisation	3, 5, 6, 7, 8, 10, 13
Visualisation of costs/benefit/action lines	10, 13
Visualisation of cross sectoral regulations	1
Visibility of impact on multiple stakeholder	9, 10
Visibility of impact on process flows due to departmental legislation	1
Visual representation of project milestones	3

4.2.2 Challenges and Critical Success Factors for City Process Modelling

During the interviews, the participants were asked to reflect upon the challenges of CPMo and the current approaches that were being used. They discussed the different types of challenges and issues that were encountered by the multiple stakeholders when the processes were mapped or explored for improvements (Table-5). They considered these as a kind of process modelling. The ideal CPMo should address or resolve these challenges, in order to successfully model the complex cross-sectoral city processes.

Table-5: Challenges encountered during city process modelling (interview findings)

Challenges during CPMo
People related challenges (skills, change management, clarity of vision)
IT related challenges (varying levels of technical infrastructure in different sectors)
Information capture from organisational silos
Inefficient process captures due to organisational complexity
Non-standardisation of existing processes
Stakeholder collaboration needs

Data challenges with ownership, complexity, data compatibility, security, and privacy	
City council challenges with legislation, bureaucracy, and regulation	

The majority of the participants could verify that from the current set of approaches that were being used in SCD projects in the participant's own organisation, no single tool,technique, or language could address the challenges of CPMo. The existing tools/techniques/languages in the participant's opinion failed to meet the project management needs, cross-sectoral collaboration needs, or address the city's interoperability needs.

In addition, when interviewees were asked about the success factors for the above-mentioned challenges, the following CSFs for modelling the cross-sectoral city processes were identified (Table-6).

Table-6: CSFs for addressing possible challenges during CPMo (interview findings)

CPMo Requirements	Interviewees
Clarity of shared vision and goals for successful future state visualisation	1, 3, 4, 5, 6, 7, 8, 10, 12
Citizen participation in data gathering - required for data availability requirement for the smart city project	6, 7, 8, 10, 11, 12
Adequate IT infrastructure	6, 13
Stakeholder identification, communication, engagement commitment, and management (cross sectoral, multiple service providers)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
Selection of ideal tool for accurate process capture	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12
Cross sectoral project collaboration	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
Appropriate Information and Requirements gathering methodology	1, 5, 7, 8, 9, 10, 12
Availability of skilled workforce	2, 3, 8, 10, 11, 13
Identification of mandates of stakeholders and identification of how the mandates intersect each other	5

During the interviews, it was mentioned on a singular occasion (interviewee 7) that having an exclusive technology-led approach for developing smart cities is a leading cause of failures for SCD projects. Although not being repeated by other participants during discussions, it is significant due to the reason that 'inclusive cross-sectoral stakeholder participation' has been the most cited requirement for successful CPMo. Moreover, as every city council has its own regulation and every sector has its own legislation framework, to enable cross-sectoral collaboration, overlaps in these areas will need to be identified during the modelling stage.

5. Discussion of the findings to design a framework for developing CPMo approaches

From the literature analysis and primary research, we have obtained the following two components:

Capabilities- These are the main capabilities of existing BPMo tools, techniques, and languages from the literature (identified in 4.1).

Requirements- These are the expectations of the stakeholders and the ideal requirements, which the CPMo should address to be able to model the cross-sectoral processes for SCD (identified in 4.2.1). Similar requirements in terms of the meanings were grouped together.

To develop a framework for developing CPMo, these two components from Table-2 and Table-4 are mapped with each other to find out if the existing capabilities are matched with the expected requirements (Figure-3). If so, then it could have been concluded that a singular or a combination of existing BPMo was adequate to fulfil the research aim and thus, answer the research question. If not, what other elements are required to develop an appropriate CPMo approach.

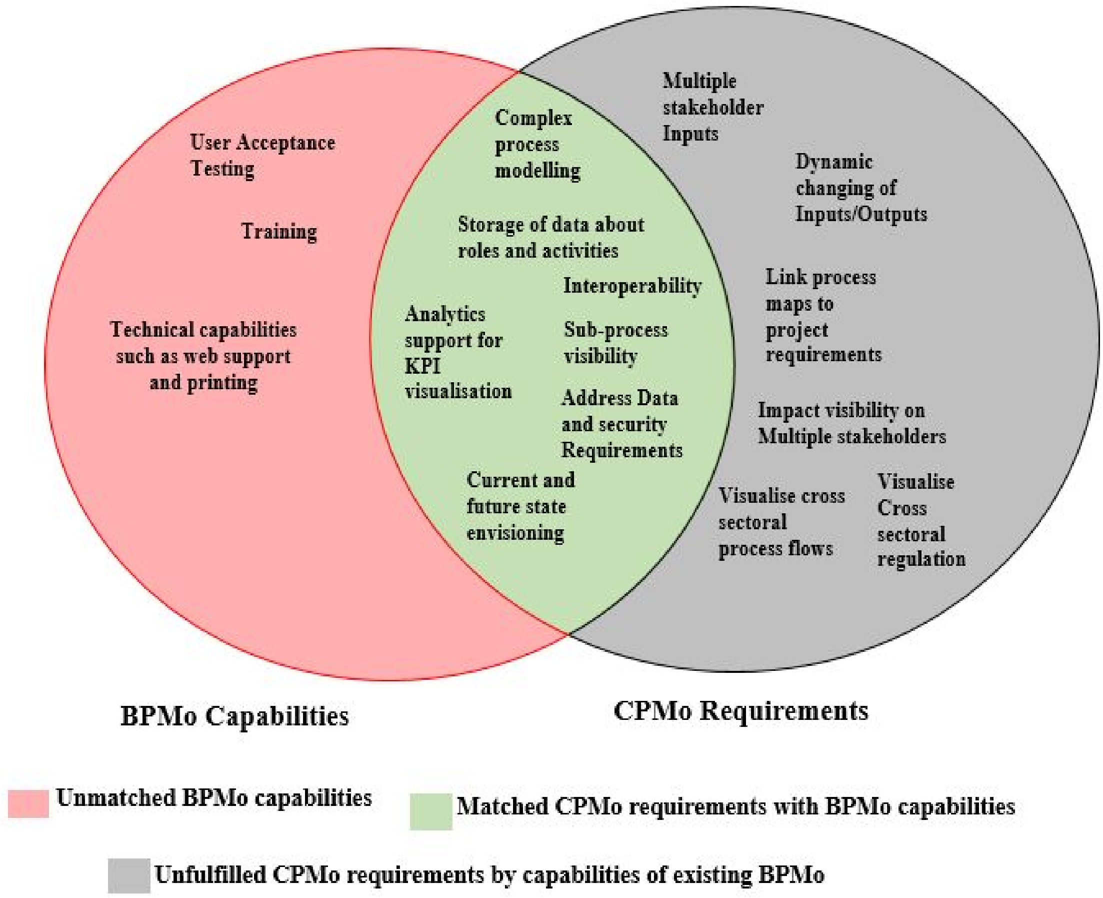

Figure-3: Mapping of BPMo Capabilities with Requirements of CPMo

Although the technical capabilities of BPMo (such as the ability to print models, post models on the web, address training capabilities and user testing) did not have an equivalent CPMo requirement need, they can still be considered as implied requirements, because an effective CPMo is needed to have these technical features.

As shown in Figure-3, the capabilities of existing BPMo tools, techniques, and languages cannot fully address all of the CPMo requirements for SCD, on their own or in combination, as too many requirements are left unfulfilled by the existing capabilities. Thus, it can also be confirmed that although

BPMN has the most capabilities to address the technical requirements in terms of the ability to model complex processes and sub-processes, it lacks the other requirements, such as the ability to represent regulatory element. Moreover, different city service authorities are governed by their own regulatory framework, hence regulatory constraints governing the individual authorities must be considered during process modelling. These findings verify that no singular BPMo tool, technique, language, or a combination of them is suitable to fully address the needs of cross-sectoral process modelling for the purpose of SCD.

Hence, it will be necessary to develop an innovative CPMo framework for SCD. This will be carried out by using the unfulfilled requirements of existing BPMo capabilities. In addition, the challenges and CSFs identified in 4.2.2 bring additional dimensions to develop this innovative framework. Figure-4 presents the CPMo framework that acts as a guide to develop a CPMo approach. Components of this framework have been identified from the unfulfilled CPMo requirements, which are necessary for SCD. Also, the challenges and CSFs as identified from the primary research have provided additional dimensions for the framework.

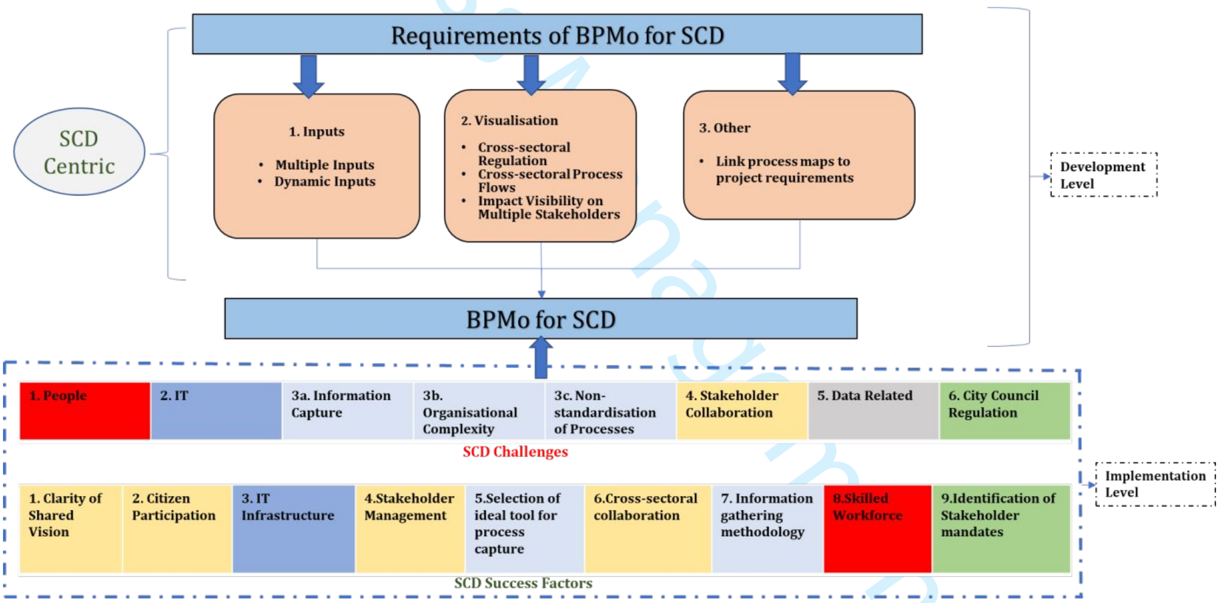

Figure-4: A framework for developing CPMo approach

As shown in the framework, the critical unmet requirements are further grouped into "input", "visualisation", "other" requirements from BPMo. The ability of BPMo to accept multiple inputs and dynamically changing inputs as the project requirements change was cited as being extremely important. Another significant requirement was related to the visualisation aspect of the BPMo, namely the visualisation of cross-sectoral regulation in the process modelling e.g. the impact of data regulation on collaboration projects between city service providers, such as NHS and Transport. It was also necessary to visualise the impact of process change on multiple stakeholders as a result of the SCD initiative. Another BPMo requirement was the ability to link process maps to project requirements. These requirements are SCD centric and will need to be addressed during the development level.

At the implementation level, the challenges encountered during CPMo will need to be addressed as well. The challenges identified in the primary research were further grouped together based on the similarities of their context. Success factors that can resolve these challenges were colour coded in the figure and have been explained below:

1. People related challenges, which can be addressed by several success factors, such as ensuring the availability of skilled workforce before the implementation of SCD projects;
2. IT challenges: availability of adequate infrastructure to ensure successful implementation post modelling;
3. Information capture from organisational silos, organisational complexity and non-standardisation of processes: city service authorities are organisationally complex and usage of the most appropriate information gathering methodology and selection of an ideal approach for accurate process capture can address these challenges related to process modelling;
4. Stakeholder collaboration: to resolve this challenges, it will be necessary to perform extensive stakeholder management, consisting of cross-sectoral stakeholder identification, relevant to the smart city initiatives. This has been cited as a success factor by almost all research participants. Clarity of shared vision and citizen participation with comprehensive communication and engagement plans are necessary to ensure continuous engagement and commitment to SCD initiative. Hence, co-ordination between these stakeholder groups is extremely important for successful city process modelling;
5. Data related challenges: data is stored in different formats across different city services and it will be necessary to resolve this challenge at implementation level;
6. City council regulation challenges: as identified from the primary research, the regulation differs considerably between different cities and local administrative bodies. Also, the service providers have their own legal framework. Hence identification of overlaps and conflicts in the early stages is important. The BPMo developers will need to consider regulation as an input, along with identification of stakeholder mandates which will help resolve potential conflicts in cross-sectoral process mapping.

5.1 Positioning the CPMo framework in the body of knowledge

The CPMo framework, developed in this study can be positioned in several areas, in order to add value to the existing smart city related frameworks.

In the four stages of the smart city framework based on the BPR principles (Budhiputra and Putra, 2016), namely identification of citizen's problems, business process assessment, developing use case and identification of vertical solutions and solution implementation, there is a requirement of tools at every step in order to achieve business process standardisation. The new CPMo will enable identification of the bottlenecks in the current systems and help to achieve business process standardisation which is an operational motivation driver and in fact a goal of any change of business processes, as well as the end vision of this framework (Al-Mashari et al., 2003; Davenport et al., 2004).

The CPMo framework developed in this study can provide a modelling dimension to the input component of the Smart City Initiatives Design (SCID) Framework (Ojo et al., 2015), thus helping to explore its usability in terms of practical application.

In the smart city landscape model (Jamous and Hart, 2019), the CPMo framework can enable the interconnection of its components, which are smart energy, smart logistics, smart traffic management and smart places, all linked using Point to Point (P2P) approach.

In the Smart Asset Alignment to Citizen Requirements Framework (SAACRF) proposed by Heaton and Parlikad (2019) the alignment of the city's services according to citizen's needs has been proposed. The data model integration layer between the services and citizens requirements aims to address the interoperability needs but it lacks any discussion about process modelling, which is needed to enable this transformation. The CPMo framework can provide the missing dimension to this framework with impact visualisation on multiple stakeholders with systems integration.

A data analytics-based framework proposed by Puiu et al. (2016), which aims to collect raw data from multiple sources in the city and convert it into actionable information, thus helping to create insightful smart city applications, provides integration of heterogeneous data streams, providing interoperability, quality analysis, and real-time data analytics and application development. Using the CPMo framework, developed in this study can be useful in the practical implementation of the Puiu et al.'s framework, as it will address the process modelling requirement which is needed in the development phase.

The generic SCD framework (BSI, 2015) is built on the concept of integration of physical, human and digital systems with a view to delivering a sustainable smart city (BSI, 2014) and thus supports the underlying foundation of a smart city from an ESI perspective. This framework is intended to be used to set a smart city strategy for the urban policymakers and city governments, so although it addresses the 'What' element as in, 'what does a city need to be smart?, it does not address the 'how' (i.e. the methodology required to enable the transformation). Hence, the CPMo framework of this research can be used with the SCFs as it will fulfil the criteria *[B] cross-city governance and delivery processes*. Specifically *[B2] Transforming the city's operating model* by enabling BPC for SCD can be achieved by using the CPMo framework to model the complex cross-sectoral city processes.

The CPMo framework can also provide the dimension of intercity process modelling to the SC model which is based on a business model canvas (Giourka et al., 2019). The original smart city model does not address the roadmap to achieve this transformation and does not identify the challenges associated with this process. Using the CPMo framework will provide the missing dimension and helps to validate the value proposition of this smart city model.

The smart city framework proposed by Pettit et al. (2018) defines a smart city as one that is built on the overlapping dimensions of culture, metabolism and governance. The authors define metabolism as the element that enables the introduction of new technology in the city to address the city's problems (traffic, recycling, etc.) while improving liveability and the city's economic performance. The CPMo framework can address the integration requirement of this framework thus proposing its usefulness for practical implementation for SCD.

To address shared infrastructure and challenges (Chorabi et al., 2012) in a smart city, it is necessary to have cross-sectoral collaboration and interoperability of systems. Interoperability is the ability of systems to share data and turn information into action without any access, implementation or usage constraint (Minetti, 2020). Modelling the processes as they flow through the legacy systems will enable the solutions developers to address the interoperability requirement which is necessary for systems integration for the purpose of SCD. The frameworks discussed in this section fail to address the city's interoperability and system integration requirements on their own. Using the innovative CPMo framework of this study in conjunction with these frameworks will add this missing dimension to enable development of smart cities.

6. Conclusions

To transform a city into a smart city, there is a need to integrate complex sub-systems and change legacy cross-sectoral city processes. Systems integration in the private sector requires BPC as an essential part of it. To achieve BPC, there are many BPMo approaches, utilised by various tools, techniques, and languages available. The focus of this research was to identify the most appropriate BPMo approach for the purpose of SCD (CPMo). Current literature was analysed to identify if any of the existing modelling approaches in ESI on its own or in combination with others were suitable to achieve this purpose. Literature analysis revealed that there was a significant lack of discussion on this topic; as such, the research gap was confirmed. In order to answer the research question, the research methodology was designed to gather data from primary research. The research participants were interviewed remotely, and questions were formulated to derive insights from their experience on having been involved in changing and modelling cross-sectoral city processes for SCD projects. The data was qualitatively analysed to identify the current capabilities of existing BPMo tools/techniques/languages and map them with CPMo requirements in the SCD context. The results of this mapping indicated that not all CPMo requirements were fulfilled from current BPMo capabilities. Therefore, the main components of CPMo framework (the outcome of this research) were established. In addition, based on the qualitative data analysis, the challenges encountered during CPMo and the critical success factors added additional dimensions, which will prove useful in the implementation stage of this framework. Hence, the CPMo framework was fully developed to act as a guide for developing CPMo approaches for SCD purposes.

6.1 Research contributions

Yet, the city councils' approach towards attaining a smart city vision has been to deploy point solutions developed by technical solution providers to solve specific problems in a city. In addition, as discussed in this research, current smart city roadmaps, and assessment frameworks lack the process change and modelling elements, which are necessary to achieve SCD. This research attempted to address these deficiencies by developing a CPMo framework, which can also compliment the existing SCD frameworks (as discussed in 5.1). In summary, the main contributions of this research have been categorised into the following two categories:

1. Practical contributions:

The innovative CPMo framework developed in this research fills the gap posed by existing SCD frameworks by employing a step by step approach to help make the transition from the current state to future state of SCD, especially from city systems integration viewpoint. in addition, this framework endeavours to provide a guideline for smart city solution providers to develop new tools/techniques/languages for CPMo. The framework also guides city authorities and smart city developers to build/improve their SCD roadmap, through providing an insight regarding the necessity of considering cross-sectoral city systems integration, BPC, and CPMo, when developing their roadmap. Moreover, the framework helps smart city developers to better understand the challenges that can be faced during cross-sectoral city systems integration and city process change and enhances their capabilities to address those challenges.

2. Theoretical contributions:

This research proved that developing an appropriate CPMo approach for SCD is necessary, since none of the current BPMo approaches is fully applicable for cross-sectoral city process change. The CPMo framework also contributes in addressing some of the BPC challenges for SCD, such as clarification and understanding, BPC monitoring challenge, standardization, interoperability, agility and flexibility, and interdependencies. Furthermore, this research justified that the learnings from ESI can be useful for SCD context, as during this study the ESI learnings were utilised to develop the CPMo framework and to address the challenges involved.

6.2 Research limitations and recommendations for further research

Similar to any other qualitative research the number of participants can be questioned as a limitation of the study. However, in this research, after 10 interviews a saturation point was met, where no new findings regarding the SCD centric requirements of CPMo were recognised. Then, three more interviews were also conducted to confirm the saturation point. In addition, a global geographical range of experts was interviewed to gather opinions from various cities in the world, such as Barcelona, Rome, Jakarta, and Sydney, to ensure the generalisability of the study was met. In addition to this, most of the interviewees were able to utilise their experiences from various sectors, councils, IT companies, and consultancy groups, so that various opinions from different SCD strategies and approaches were utilised in this study. Hence, 13 semi-structured interviews provided sufficient data to achieve the outcome of the research.

This study developed a novel CPMo framework to guide smart city developers and solution providers for their future SCD related developments. Therefore, it will be necessary to utilise the CPMo framework for developing tools, techniques, and languages for modelling cross-sectoral processes for the purpose of SCD. Consequently, the framework can be implemented for a SCD project and changing cross-sectoral city processes among various city sectors, hence ensuring the practical validation of the CPMo framework.

References

Abdel-Fattah, M.A., Khedr, A.E. and Aldeen, Y.N., 2017. An evaluation framework for business process modeling techniques. International Journal of Computer Science and Information Security (IJCSIS), 15(5), pp.382-392

Abu-Shanab, Emad and Bataineh, L. (2015) Challenges facing E-government projects: How to avoid failure, 4, pp. 207-217.

Aldin, L. and De Cesare, S., 2009. A comparative analysis of business process modelling techniques.

Al-Mashari M, Al-Mudimigh A and Zairi M (2003) Enterprise resource planning: A taxonomy of critical factors. *European Journal of Operational Research* 146(2): 352–364.

Angelidou, M., (2017) Smart city planning and development shortcomings. TeMA-Journal of Land Use, Mobility and Environment, 10(1), pp.77-94.

Anthopoulos L and Giannakidis G (2017) Task-based process modeling for policy making in smart cities. *Proceedings of the 2016 ITU Kaleidoscope Academic Conference: ICTs for a Sustainable World, ITU WT 2016*. Institute of Electrical and Electronics Engineers Inc. DOI: 10.1109/ITU-WT.2016.7805707.

Asq (2019). What is a Flowchart? Process Flow Diagrams & Maps | ASQ. [online] Available at: https://asq.org/quality-resources/flowchart.

Bandara W, Gable GG, Tate M, et al. (2021) A validated business process modelling success factors model. *Business Process Management Journal* 27(5). Emerald Publishing Limited: 1522–1544. DOI: 10.1108/BPMJ-06-2019-0241.

Beauchamp, G. (2020) Why & How: Business Process Modelling - Business Analyst Community & Resources | Modern Analyst. [online] www.modernanalyst.com. Available at: https://www.modernanalyst.com/Resources/Articles/tabid/115/ID/864/Why-How-Business-Process-Modelling.aspx.

Birkmeier, D.Q., Kloeckner, S. and Overhage, S. (2010) An empirical comparison of the usability of BPMN and UML activity diagrams for business users.

BSI. (2014) Code of practice for Smart city framework: Guide to establishing strategies for smart cities and communities. [SOURCE: PAS 180:2014, 3.1.62]

BSI (2015). PAS:181 – Smart Cities Framework | BSI Group. [online] Available at: https://www.bsigroup.com/en-GB/smart-cities/Smart-Cities-Standards-and-Publication/PAS-181-smart-cities-framework/.

Budhiputra, P., M. & Putra, K., P. (2016) "Smart city framework based on business process re-engineering approach", IEEE, pp. 69.

Bhaskar, H., L. (2018) Business process reengineering framework and methodology: a critical study. International Journal of Services and Operations Management, 29(4), p.527.

Chen, Y., T. and Wang, M., S. (2017) A study of extending BPMN to integrate IoT applications, International Conference on Applied System Innovation (ICASI), Sapporo, Japan.

Chourabi, H., et al. (2012) “Understanding Smart Cities: An Integrative Framework,” in 2012 45th Hawaii International Conference on System Sciences, pp. 2289–2297.

Coleman, J. (2013) Data flow sequences: A revision of data flow diagrams for modelling applications using XML. International Journal of Advanced Computer Science and Applications (ijacsa), 4(5), pp.28-31.

Cornesse, C., Blom, A.G., Dutwin, D., Krosnick, J.A., De Leeuw, E.D., Legleye, S., Pasek, J., Pennay, D., Phillips, B., Sakshaug, J.W., Struminskaya, B. and Wenz, A. (2020). A Review of Conceptual Approaches and Empirical Evidence on Probability and Nonprobability Sample Survey Research. Journal of Survey Statistics and Methodology, 8(1), pp.4–36.

Creswell, J., W. (2015) A concise introduction to mixed methods research, SAGE, Los Angeles

Davenport TH, Harris JG and Cantrell S (2004) Enterprise systems and ongoing process change. *Business Process Management Journal* 10(1). Emerald Group Publishing Limited: 16–26.

DeLusignan, S., Krause, P., Michalakidis, G., Vicente, M.T., Thompson, S., McGilchrist, M., Sullivan, F., van Royen, P., Agreus, L., Desombre, T. and Taweel, A., (2012) Business process modelling is an essential part of a requirements analysis. Yearbook of Medical Informatics, 21(01), pp.34-43.

Finney S and Corbett M (2007) ERP implementation: a compilation and analysis of critical success factors. *Business Process Management Journal* 13(3). Emerald Group Publishing Limited: 329–347.

Flick, U (ed.) (2013) The SAGE Handbook of Qualitative Data Analysis, SAGE Publications, London. Available from: ProQuest Ebook Central.

Forliano C, De Bernardi P, Bertello A, et al. (2020) Innovating business processes in public administrations: towards a systemic approach. *Business Process Management Journal* 26(5). Emerald Publishing Limited: 1203–1224. DOI: 10.1108/BPMJ-12-2019-0498.

Gascó-Hernandez, M., (2018) Building a smart city: lessons from Barcelona. Communications of the ACM, 61(4), pp.50-57.

Giourka, P., Sanders, M.W., Angelakoglou, K., Pramangioulis, D., Nikolopoulos, N., Rakopoulos, D., Tryferidis, A. and Tzovaras, D., 2019. The smart city business model canvas—A smart city business modeling framework and practical tool. Energies, 12(24), p.4798.

Girardi, P. and Temporelli, A., (2017),' Smartainability: a methodology for assessing the sustainability of the smart city'. Energy Procedia, 111(1), pp.810-816.

Harmon P (2003) *Business Process Change: A Manager's Guide to Improving, Redesigning and Automating Processes*. San Francisco: Morgan Kaufmann Publishers.

Harmon, P. and Wolf, C. (2011) Business process modelling survey. Business process trends, 36(1), pp.1-36.

Harmon, P. (2014) Business process change: a business process management guide for managers and process professionals, 3rd edn, Morgan Kaufmann, Amsterdam.

Heaton, J. and Parlikad, A., K. (2019) A conceptual framework for the alignment of infrastructure assets to citizen requirements within a Smart Cities framework. Cities, [online] 90, pp.32–41. Available at: https://www.sciencedirect.com/science/article/pii/S0264275118304384.

Ibrahim, M., El-Zaart, A. & Adams, C. (2018) "Smart sustainable cities roadmap: Readiness for transformation towards urban sustainability", Sustainable cities and society, vol. 37, pp. 530-540.

Jacobsen, H.A., Li, G., and Muthusamy, V. (2010) A distributed service-oriented architecture for business process execution. ACM Transactions on the Web (TWEB), 4(1), pp.1-33.

Jamous, N. and Hart, S.W. (2019) Towards an Integration Concept of Smart Cities. 2019 2nd International Conference on new Trends in Computing Sciences (ICTCS).

Javidroozi, V., Shah, H., Cole, A. and Amini, A. (2014) Smart City as an Integrated Enterprise: A Business Process Centric Framework Addressing Challenges in Systems Integration, pp. 20-24.

Javidroozi, V., Shah, H., Cole, A. and Amini, A. (2015) Towards a City's Systems Integration Model for Smart City Development: A Conceptualization, International Conference on Computational Science and Computational Intelligence (CSCI), pp. 312–317.

Javidroozi V, Shah H and Feldman G (2019) A framework for addressing the challenges of business process change during enterprise systems integration. *Business Process Management Journal* 26(2). Emerald Group Publishing Ltd.: 463–488.

Javidroozi, V., Shah, H. and Feldman, G. (2019) Urban Computing and Smart Cities: Towards Changing City Processes by Applying Enterprise Systems Integration Practices, IEEE Access, 7, pp.108023-108034.

Johansson, L., Wärja, M. & Carlsson, S. (2012) An evaluation of business process model techniques, using Moody's quality criterion for a good diagram.

Karhof, A., Jannaber, S., Riehle, D.M., Thomas, O., Delfmann, P. and Becker, J. (2016) On the de-facto standard of event-driven process chains: reviewing EPC implementations in process modelling tools. Modellierung.

Khan, S.M., Sulgrove, A., Silverberg, R., Loderup, M. and Berst, J. (2017) Smart Cities and Communities GDT Smart City Solutions on Intel ® -based Dell EMC infrastructure.

Komninos, N. and Mora, L., 2018. Exploring the big picture of smart city research. Scienze Regionali, 17(1), pp.15-38.

Knox, S. and Burkard, A. (2009) Qualitative research interviews: Psychotherapy Research, 19(4-5), pp.566-575.

Lederer M, Quitt A, Büsch M, et al. (2020) One size fits all An analytical approach how to make use of process modelling techniques for different fundamental supply chain types. *International Journal of Supply Chain and Operations Resilience* 4(1). Inderscience Publishers: 1. DOI: 10.1504/IJSCOR.2020.105948.

Legner C and Wende K (2007) 'The Challenges of Inter-organizational Business Process Design – a Res' by Christine Legner, et al. In: *European Conference on Information Systems (ECIS 2007)* (eds H Österle, J Schelp, and R Winter), 2007, pp. 1643–1654.

Lom, M. & Pribyl, O. (2020) "Smart city model based on systems theory", International journal of information management, pp. 102092.

Lombardi, P., Giordano, S., Farouh, H. and Yousef, W. (2012) Modelling the smart city performance. Innovation: The European Journal of Social Science Research, 25(2), pp.137-149.

Medoh, C. and Telukdarie, A. (2017) Business process modelling tool selection: A review, IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), Singapore, pp. 524-528.

Mendling, J., Reijers, H.A. and van der Aalst, W.M.P. (2010). Seven process modelling guidelines (7PMG). Information and Software Technology, 52(2), pp.127–136.

Minetti, G. (2020) Creating truly open cities: why interoperability and 6LoWPAN matter. [online] Smart Cities World.

Mohammadi, M. and Mukhtar, M. (2012) Business process modelling languages in designing integrated information system for supply chain management. International Journal on Advanced Science, Engineering and Information Technology, 2(6), pp.464-467.

Momoh A, Roy R and Shehab E (2010) Challenges in enterprise resource planning implementation: state-of-the-art. *Business Process Management Journal* 16(4). Emerald Group Publishing Limited: 537–565. DOI: 10.1108/14637151011065919.

Motwani, J., Mirchandani, D., Madan, M. and Gunasekaran, A. (2002) Successful implementation of ERP projects: evidence from two case studies. International Journal of Production Economics, 75(1-2), pp.83-96.

Nam, T. and Pardo, T. (2011) Conceptualizing smart city with dimensions of technology, people, and institutions, ACM, pp. 282.

Ojo, A., Curry, E., Janowski, T., and Dzhusupova, Z. (2015) "Designing Next Generation Smart City Initiatives: The SCID Framework," in Transforming City Governments for Successful Smart Cities, M. P. Rodríguez-Bolívar (ed.), Cham: Springer International Publishing, pp. 43–67

OMG. (2020) About the Business Process Model and Notation Specification Version 2.0.2. [online] Available at: https://www.omg.org/spec/BPMN/2.0.2/.

Oracle (2020) Fusion Middleware Modeling and Implementation Guide for Oracle Business Process Management. [online] Available at: https://docs.oracle.com/cd/E29542_01/doc.1111/e15176/bp_hwfconf_shared.htm#BPMPD87304.

Osman, A.M.S. (2019) "A novel big data analytics framework for smart cities", Future generation computer systems, vol. 91, pp. 620-633.

Pettit, C., Bakelmun, A., Lieske, S.N., Glackin, S., Thomson, G., Shearer, H., Dia, H. and Newman, P. (2018) Planning support systems for smart cities. City, culture and society, 12, pp.13-24.

Peldzius, S. and Ragaisis, S., 2011. Comparison of maturity levels in CMMI-DEV and ISO/IEC 15504. Applications of Mathematics and Computer Engineering, pp.117-122.

Pereira VR, Maximiano ACA and Diógenes de Souza Bido (2019) Resistance to change in BPM implementation. *Business Process Management Journal* ahead-of-p(ahead-of-print).

Pierce P, Ricciardi F and Zardini A (2017) Smart cities as organizational fields: A framework for mapping sustainability-enabling configurations. *Sustainability (Switzerland)* 9(9). MDPI AG: 1506.

Puiu, D., Barnaghi, P., Tönjes, R., Kümper, D., Ali, M.I., Mileo, A., Parreira, J.X., Fischer, M., Kolozali, S., Farajidavar, N. and Gao, F., (2016) Citypulse: Large scale data analytics framework for smart cities. IEEE Access, 4, pp.1086-1108.

Saluky, S. (2018) Development of enterprise architecture model for smart city. ITEj (Information Technology Engineering Journals), 2(2).

Schaffers H, Komninos N and Pallot M (2012) Smart Cities as Innovation Ecosystems Sustained by the Future Internet. Lyon, France.

Scheuerlein, H., Rauchfuss, F., Dittmar, Y., Molle, R., Lehmann, T., Pienkos, N. and Settmacher, U. (2012). New methods for clinical pathways—Business Process Modeling Notation (BPMN) and Tangible Business Process Modeling (t.BPM). Langenbeck's Archives of Surgery, 397(5), pp.755–761.

Scuotto V, Ferraris A and Bresciani S (2016) Internet of Things: Applications and challenges in smart cities: a case study of IBM smart city projects. Business Process Management Journal 22(2). Emerald Group Publishing Ltd.: 357–367. DOI: 10.1108/BPMJ-05-2015-0074.

Slack N, Chambers S and Johnston R (2009) *Operations and Process Management: Principles and Practice for Strategic Impact*. Prentice Hall/Financial Times.

Smartsheet (2019). Business Process Modeling and Notation (BPMN) 101 | Smartsheet. [online] Available at: https://www.smartsheet.com/beginners-guide-business-process-modeling-and-notation-bpmn.

Subhiyakto, E.R. and Astuti, Y.P. (2019) March. Design and Development Meeting Schedule Management Application using the RAD Method. In 2019 International Conference of Artificial Intelligence and Information Technology (ICAIIT) (pp. 60-64). IEEE.

Tarhini, A., Ammar, H., Tarhini, T. and Masa'deh, R. (2015) Analysis of the Critical Success Factors for Enterprise Resource Planning Implementation from Stakeholders' Perspective: A Systematic Review. International Business Research, 8(4).

Townsend AM (2013) Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia. W. W. Norton & Company. New York: W. W. Norton & Company.

Trauer J, Wöhr F, Eckert C, et al. (2021) CRITERIA FOR SELECTING DESIGN PROCESS MODELLING APPROACHES. *Proceedings of the Design Society* 1. Cambridge University Press: 791–800. DOI: 10.1017/PDS.2021.79.

Wangenheim, von, C.G., Hauck, J.C.R., Salviano, C.F. and von Wangenheim, A. (2010) May. Systematic literature review of software process capability/maturity models. In International Conference on Software Process Improvement and Capability Determiniation–Spice.

Weber, M. and Podnar-Žarko, I. (2019) A Regulatory View on Smart City Services. Sensors (Basel, Switzerland), 19(2).

Westraadt, L. and Calitz, A. (2020) A Modelling Framework for Integrated Smart City Planning and Management. Sustainable Cities and Society, p.102444.

Xu L Da (2011) Enterprise Systems: State-of-the-Art and Future Trends. *IEEE Transactions on Industrial Informatics* 7(4). IEEE: 630–640. DOI: 10.1109/TII.2011.2167156.

Cross-sectoral Process Modelling for Smart City Development

Abstract

Purpose- Integration of city systems is needed to provide flexibility, agility, and access to real-time information for the creation and delivery of efficient services in a smart and sustainable city. Consequently, City Process Modelling (CPMo) becomes an essential element of connecting various city sectors. However, to date, there has been limited research on the requirements of an ideal CPMo approach~~technique~~ and the usefulness of available Business Process Modelling (BPMo) approaches~~tools/techniques~~. This research develops a framework for CPMo to guide smart city developers when modelling city processes.

Design/Methodology/Approach- Data from literature analysis was gathered to derive capabilities of existing BPMo techniques. Then, semi-structured interviews were conducted to thematically and qualitatively explore the requirements, challenges, and success factors of CPMo.

Findings- The interview findings offered 17 requirements to be addressed by a CPMo approach~~technique~~, along with several challenges and success factors to be considered when implementing CPMo approaches~~techniques~~. Then, the paper presents the results of mapping these requirements against 12 existing BPMo capabilities, identified from the literature, concluding that a significant number of requirements (which are mainly related to inputs and visualisation) have been left unfulfilled by existing BPMo approaches~~tools/techniques~~. Hence, developing an innovative CPMo approach~~technique~~ is necessary to address the components of unfulfilled requirements.

Originality/value- The innovative framework presented in this paper justifies the CPMo requirements, which are unexplored in existing SCD frameworks. Moreover, it will act as a guide for smart city developers, to model cross-sectoral city processes, helping them progress their SCD road map and make their cities smart.

Keywords: City process modelling, Business process modelling, smart cities, smart city development, Business process management

Article Type: Research paper

1. Introduction

Smart City Development (SCD) was introduced to resolve urbanisation problems, such as overpopulation, overuse of resources, environmental problems, economic and social issues (Javidroozi et al., 2019; Jamous and Hart, 2020). With the aim to improve the citizens' lives by streamlining the service delivery, globally the city authorities are actively investing in technology-led initiatives aimed at transforming the cities into smart cities (Girardi and Temporelli, 2017; Komninos and Mora; 2018). On the other hand, a city is regarded as an integrated system, consisting of many sub-systems, such as healthcare, transport, education, energy, housing, as well as several management authorities and agencies that run these systems (Javidroozi et al., 2015; Pierce et al., 2017). The systems integration concept in SCD has also been further explored in the smart city initiatives framework, where a smart city has been envisioned as an integrative framework of components, such as management and organisation, technology, governance, policy, people and communities, economy, built infrastructure and the natural environment (Chourabi et al., 2012). Thus, city systems integration is a necessity for SCD, resulting the integration of people, institutions, and technology-mediated services that is similar to Enterprise Systems Integration (ESI) in the private sector, where Business Process Change (BPC) enables enterprises to integrate disjointed information systems and achieve operational efficiency (Motwani et al., 2002; Nam and Pardo, 2011; Harmon, 2014). This indicates that ESI and SCD have similar aims and objectives from systems integration perspectives, so that smart city can be considered as a large-scale, complex, and integrated enterprise, in order to utilise the learnings from enterprises for addressing the relevant SCD challenges. Consequently, BPC ~~is~~ also becomes an essential part of city systems integration in SCD, in order to offer efficient services to citizens in real-time (Javidroozi et al., 2014 and 2019).

BPC is a complex task, which encompasses several steps and challenges to be considered and addressed. The challenges, such as inter-dependencies, standardisation, flexibility, agility, governance, and interoperability of business processes are some examples that need to be carefully measured and sustained during BPC and it cannot be achieved without the use of methods that have been developed to facilitate the process of BPC, depending on the type and scale of the change. Business Process Modelling (BPMo) is one the methods, which plays a central role to understand the existing processes, identify the issues, address the challenges, justify the necessity of change, and most importantly to redesign the processes and align them with the purpose of systems integration (Javidroozi et al., 2019). In addition, choosing an appropriate BPMo tool supports the efficiency of BPC. Moreover, the visualisation offered by an appropriate BPMo tool helps comprehend existing processes and reduce the wasteful activities within a process, so that provides more efficiency for business processes (Slack et al., 2009; Xu, 2011) and offers a basis to the orchestration of technological enablers along business processes (Bandara et al., 2021). ~~.~~

The concept of BPMo and its various tools, techniques, and languages ~~The concept of Business Process Modelling (BPMo) in ESI context has also~~have ~~-~~been extensively discussed in the ESI context~~literature~~, with respect to the methodologies, guidelines, and design of the frameworks and techniques to facilitate BPC and addressing related challenges (~~(~~Harmon and Wolf, 2011; Bhaskar, 2018). ~~In addition, research has indicated that critical success factors and challenges of BPC in ESI and SCD are similar (Javidroozi et al., 2019) and as such, it can be concluded that using an appropriate process modelling technique for the purpose of SCD (referred to as City Process Modelling (CPMo) in this research) will help redesigning cross-sectoral city processes and addressing the challenges involved.~~ However, ~~a literature review carried out on CPMo revealed that~~ very limited research has been carried out ~~o~~in the use of appropriate process modelling approaches for the purpose of SCD (referred to as City Process Modelling (CPMo) in this research)~~this area~~ (Forliano et al., 2020), while the critical success factors and challenges of BPC in ESI and SCD contexts are similar (Javidroozi et al., 2019) and as such, it can be concluded that CPMo will help redesigning cross-sectoral city processes and addressing the challenges involved.~~and~~ Nevertheless, no recommendations have been made for a specific process modelling tool ~~approach, tool, or technique~~ for the purpose of SCD, while it is crucial for city authorities to effectively innovate their business processes in this systemic context towards becoming smart (Forliano et al., 2020). However, there is a wider discussion about different frameworks to transform a city into a smart city based on various dimensions of technology application and people management. For example, the integration landscape model proposed by Jamous and Hart (2019), which incorporates multiple smart cities' frameworks, as well as integration approaches of enterprises to support the orchestration of smart city services. Although the model addresses the integration problem of smart cities' services with a combination of multiple approaches, it significantly lacks the discussion regarding process modelling, which is needed for the proposed framework to be viable. Even the Smart City Framework (BSI, 2015), which is a generic framework for guiding the city leaders in realising the smart city vision in collaboration with all key stakeholders and follows a citizen-centric approach, does not provide a clear direction regarding city systems integration and its components including BPC and CPMo.

Hence, it is evident that very limited to none academic research have discussed CPMo and the selection of an approach ~~tool/technique~~ to model the cross-sectoral city processes for SCD. As a result, a comprehensive research including data gathering from primary sources is necessary to close the gap in the literature and to answer the following research question: "what are the characteristics of an appropriate approach for city process modelling?"

To answer the research question, the characteristics of an appropriate CPMo approach should be discussed with SCD experts and who are involved with changing city processes for the purpose of SCD. It should also be realised that if the existing resources are able to offer those required characteristics. Then, the characteristics of CPMo from various dimensions should be presented to guide smart city process modellers. Therefore, ~~T~~this research will review the existing process modelling approaches, utilised by various tools, ~~and~~ techniques, and languages in various contexts such as ESI, and aims at developing a framework for modelling city processes that would act as a basis for further developments of process modelling approach~~techniqu~~es in the SCD context. The following objectives will be addressed to achieve the aim of this research, hence answering the research question:

- Objective 1: To explore existing BPMo tools, ~~and~~ techniques, and languages and critically review them for the purpose of SCD by identification of their capabilities in the SCD context;
- Objective 2: To identify the requirements and expectations for modelling cross-sectoral city processes, as well as possible challenges, and critical success factors associated with the modelling, through semi-structured interviews;
- Objective 3: To map the existing BPMo capabilities against the CPMo requirements or expectations identified in the previous objectives and to discuss if the requirements of CPMo

for SCD can be fulfilled by a single, or a combination of already existing BPMo tools/techniques/languages;

- Objective 4: To develop an innovative framework for CPMo to guide future development of CPMo tools.

The first objective will help to understand the competences available within the ESI context. The second objective provides information regarding what is required for modelling city processes. Next, the results of these two objectives will be compared to realise if the existing competences from ESI are sufficient for CPMo? Then, all the findings will be drown together to present the characteristics of a CPMo approach.

Accordingly, Nthe next section will analyse the existing literature regarding process modelling in ESI and SCD contexts. The research methodology has been explained in section 3, outlining how the objectives of the research are achieved. Next, the research findings will be presented in section 4. In section 5, a discussion of the results will be offered and the CPMo framework will be developed and presented. Section 6 concludes the research, its outcomes, and contributions.

2. Theoretical backgroundMotivation of the research: existing research in CMPo

The concept of smart city has been explained by earlier researchers and smart city experts, so that many definitions have been offered in various aspects of the city, such as technology, people, environment, process, economy, services and so forth. These definitions are mainly provided based on the requirements of a particular project or the researchers' interest. For example, Schaffers et al. (2012) rely on technological innovations and discuss that smart city improves inhabitants' quality of life by utilising IT solutions. Nam & Pardo (2011) emphasised "process" as the most important factor in SCD. Townsend (2013) mainly focuses on "people" as a central element of SCD.

Nevertheless, although most of the earlier smart city research projects are towards enhancing liveability and sustainability of the future cities, they have been mainly defined smart city from the technological solutions viewpoint without discussing other aspects, especially the organisational fields. Moreover, they are often concentrated on a single city sub-system, lacking a cross-sectoral vision for transforming a city as a whole (Pierce et al., 2017).

As discussed previously, since city is a complex system of systems and city systems integration is a necessity for SCD, while this study acknowledges the crucial role of technology infrastructure (e.g. Internet of Things (IoT)) as an integration enabler (Scuotto et al., 2016), it utilises the smart city definition provided by Javidroozi et al. (2019), which is mainly focused on cross-sectoral city systems integration for developing a smart city, as a complex and integrated system of systems. Accordingly, since the existing city processes may not allow such a transformation, using an appropriate process modelling approachtechnique for changing cross-sectoral city processes is essential to provide integrated and smart services for citizens in real time. In the light of this, by considering a city as an integrated enterprise, learnings from ESI will be useful to transform the cross-sectoral city process (Javidroozi et al., 2014).

To change business processes in ESI there are several approaches ~~tools/techniques available~~, utilised by various tools, techniques, and modelling languages; most popular ones being Flowcharts, Data Flow Diagrams (DFD's), Integrated Definition for Function Modelling (IDEF), Role Activity diagram (RAD), Petri Nets, Business Process Model and Notation (BPMN), Unified Modelling Language (UML), and so on~~.~~ (Harmon and Wolf, 2011). The selection of an appropriate ~~tool/technique~~approach is based on the project requirements. Since a city is a complex system of sub-systems with cross-sectoral processes supported by a regulatory framework (Gascó-Hernandez, 2018), to achieve BPC at the city level, it will be necessary to assess these approach~~tools~~ and explore their capabilities to determine if they match the requirements of cross-sectoral CPMo. In a survey conducted by Harmon and Wolf (2011), BPMN2.0 was listed to be the tool of choice for process redesign or improvement in enterprises across various departments. However, no such research exists for the selection of BPMo approach ~~tools or techniques~~ to act for the purpose of CPMo. As explained by (Anthopoulos and Giannakidis, 2017), in some cities such as Trikala in Greece, a process was modelled by connecting the required tasks and their components. The authors believe that such modelling approach can be considered as a guide for other business processes. However, based on the argument of this paper, there should be a proper guidance to help process modellers utilise a process modelling approach for making the city processes smarter.

There are several comparisons and evaluation frameworks for selection of BPMo tool/technique/language ~~selection~~ in ESI context and evaluation approaches to assist decision-making (Medoh and Telukdarie, 2017). The current literature on BPMo application in SCD context focuses on the BPMo capabilities and suitability in a specific area of implementation. Two examples are the comparison of DFD~~'s~~ with UML with respect to requirement gathering in healthcare research (DeLusignan et al., 2012), and suitability of BPMN for the planned modelling and imaging of clinical pathways owing to its technical ability to model complex processes and decision-making abilities (Scheuerlein et al., 2012). The first one facilitated more effective stakeholder engagement with clinical research and trials, due to the use cases developed with UML being visual in nature. It also helped to consolidate data repositories, which were in various formats and disparate locations across multiple healthcare settings. In the second comparison, the technical capabilities of BPMN with respect to the ease of graphical imaging of complex processes, integration of checklists, guidelines, and medical documents proved effective in developing the clinical pathways (Scheuerlein et al., 2012).

Some researchers (e.g. Mendling et al., 2010) have proposed setting guidelines for addressing the quality of BPMo approaches~~process modelling techniques or tools~~ with the goal of reducing the error probability of the output by reducing extensive multiple branching. These guidelines use as few elements in the model as possible, minimise the routing paths per element to control the number of input and outputs, use one start and one end event, build the model as structured as possible, avoid 'OR' routing, use verb-object activity labels, and decompose the model, if it has more than 50 elements. These will help reduce the error probability by 50%. However, these guidelines ~~This approach is~~are unsuitable for SCD as in a city; different departments and stakeholders have different requirements and expectations in relation to a SCD project and as such, the requirements are very complex by nature.~~.~~

~~Some authors (e.g.~~ Chen and Wang~~,~~ (2017) have also discussed using process modelling techniques~~tools, such as~~ (e.g. BPMN) and languages (e.g. eXtensible Mark-up Language (XML)) to develop processes for connecting IoT devices in SCD projects, but their research lacks discussion about its suitability for cross-sectoral city systems integration. In the integration of the triple helix framework with the Analytic Network Process (Lombardi at al., 2012) to model, cluster, and measure the performance of smart cities and cyber-physical systems (Lom and Pribyl, 2020), the smart city is compared with the environment and the systems within the city (energy, transport, buildings). In this comparison, it has been evident that the standalone systems interact only with their environment in traditional cities. However, smart city requires the systems to be interconnected with each other, so that the issue of interoperability becomes a major challenge that needs to be considered. Hence, ~~However,~~ there is a significant lack of discussion on the cross-sectoral process modelling or systems integration aspect of SCD.

Furthermore, "data" as the core component of building a smart city has been discussed by several authors and as such, several frameworks have been proposed around this concept (e.g. Osman, 2019). However, as previously discussed, nearly all frameworks lack a comprehensive consideration of cross-sectoral process modelling. For instance, Osman's (2019) framework, which follows a layered and data driven design approach based on real-time and historical data analytics, focuses on the data element of SCD, not the process modelling element, which is needed to integrate the city systems, thus making it unsuitable for CPMo. This framework is based on the standardisation of data acquisition, access, and iterative/sequential data ~~focuses~~processing. ~~on the data element of SCD, not the process modelling element, which is needed to integrate the city systems, thus making it unsuitable for CPMo.~~ Another example in this context is the work carried out by Ibrahim et al. (2018) regarding the smart city roadmaps to achieve a city's vision of sustainability. The city's readiness to transform with ICT and non-ICT infrastructure has been addressed in this framework, which may be useful for the city planners to assess the infrastructure capabilities of their own city. Likewise, the framework proposed by Budhiputra and Putra (2016) is built on the BPR approach in ~~4~~four stages. At every stage, the author proposes the requirement of specific tools to assess the current business processes and to identify the problems in the existing processes with the end vision of achieving business process standardisation, but the capabilities of these tools or criteria for selection have not been discussed. Moreover, the smart city framework in PAS 181: 2015 (BSI, 2015) provides guidance for decision-makers in smart cities and communities (from the public, private and voluntary sectors) to develop and deliver smart city strategies that can transform their cities' ability to meet future challenges. The framework is incumbent upon the stakeholders involved in the smart city projects to explore the requirements and challenges of SCD through extensive requirement analysis, and it does not provide a singular set of guidelines or a systematic approach for individual city authorities for changing city processes. ~~-~~Hence, it does not provide useful information regarding CPMo. Another example is a smart asset alignment framework (Heaton and Parlikad, 2019), which is built on the Smart City Framework (BSI, 2015), where infrastructure assets are classified as per the functional outputs with the purpose of aligning the citizen's requirements with the city services. However, the framework does not address the integration aspect of the city's services, which is essential to remove siloed interactions of citizens with individual city services. Using IoT and a data-driven approach, Westraadt and Calitz (2020) have also designed smart city planning frameworks, which applies data generated by Integrated City Management Platforms (ICMPs) to identify cross-sectoral synergies and interdependencies. This framework may be useful to develop point solutions for targeted problem areas, but the primary focus of this framework being the data element, due to which it does not serve the purpose of SCD from a systems integration perspective. Next example is the Smart City Initiatives Design (SCID) Framework (Ojo et al., 2015), which is a top-level generic model of a smart city with no in-depth analysis of BPC or CPMo elements to realise the vision of perceived outputs. Finally, the representation of a higher-level conceptually integrated smart city in Jamous and Hart's (2019) framework offers a high degree of crosslinking, ensuring better process control. Although this framework represents an ideal integrated smart city, the research lacks the discussion about the methodology with respect to process change to achieve this vision.

These findings confirm the fact that there is a significant lack of literature on the discussion about process modelling concept for SCD. As a result, no singular BPMo approach ~~tool~~ or a combination of them have been proposed for modelling of city processes for SCD. Hence, this research will utilise a combination of secondary and primary research to analyse the existing BPMo tools, ~~and~~ techniques, and languages used in the ESI context and develop a framework as a guide towards developing an appropriate CPMo approach~~tool/technique~~.

3. Methodology

In order to address the research objectives outlined previously, secondary data was collected to identify the capabilities of existing BPMo tools, techniques, and languages in the context of SCD. Primary data collection via semi-structured interviews was done to find the requirements of cross-sectoral CPMo, the challenges involved and Critical Success Factors (CSFs) to address the challenges.

To explore existing BPMo tools, ~~and~~ techniques, and languages and critically review them for the purpose of SCD by identifying their capabilities for the SCD context (Objective-1), literature analysis was used. Data was collected from academic resources as well as the documents published by smart city solutions providers. Major databases such as Scopus, Science Direct, and ProQuest were used. Birmingham City University's Library search engine and Google Scholar were also applied to locate the data sources. Literature published between 2010 to 2020, peer-reviewed journals and conference papers or publications on studies conducted on the process modelling aspect of SCD projects, smart city case studies, where cross-sectoral process improvement or modification is the focus of the research were qualitatively analysed to find the ideal BPMo capabilities in SCD context.

The purpose of the primary research was to fulfil objective-2, which was to identify the requirements and expectations, as well as the challenges and CSFs for modelling cross-sectoral city processes. Nevertheless, the interview started by asking questions regarding the interviewees'' experience of using any modelling tool/technique/language for designing city processes.

The focus of primary data collection through structured interviews (Knox and Burkard, 2009) was to generate empirical data on the process modelling aspect of SCD projects. Participants for the research were identified based on individual involvement in smart city projects, business process analysis, city council governance, academic research on smart cities, and planning and coordination of smart city projects. The inclusion criteria for the selection of research participants were as follows:

- Having more than five years of experience in SCD;
- Having been directly involved with the development of a smart city, especially in BPC and CPMo projects; and
- Fitting in project management, city council governance, smart city consultation, implementation, or smart city solutions architect role categories.

These participants were then interviewed remotely via Microsoft Teams or Zoom.

Also, to ascertain generalisation of research participants, they were chosen from different parts of the world i.e., UK, EU, India, USA, and the South East. Hence, a global non-probability and purposive sampling was assured (Cornesse et al., 2020) to select interviewees based on their job affiliation and ability to provide relevant information from various smart city projects worldwide. City administrations across the world are at different levels of technical expertise and social dynamics, and such the expectations from a smart city varies greatly across the various levels of stakeholders involved in this transformation process. As a result, due to the exploratory nature of this research this sampling approach helped to capture varying experts' views on CPMo requirements from different levels of expertise and from various parts of the world. Accordingly, the following criteria were followed, when the sampling approach was implemented:

- Involved with the smart city projects, especially city process change phases;
- Fit in project management or implementation role;

- Experience:
    - Minimum of two years;
    - Gained from various levels of smart city readiness as observed from the literature.

Related to changing existing city processes;

Thirteen interviews were conducted as part of this process and Table-1 highlights the city/country and organisation/company of all the interviewees.

Table-1: Some information about interviewees

Interviewees	Smart city experiences	Total number of city councils/organisations per interviewee
Interviewee-1	Warwick, Walsall, Birmingham, Wolverhampton (England); TMS Consultancies	5
Interviewee-2	Birmingham (England); Highways England	2
Interviewee-3	Manchester (England)	1
Interviewee-4	Bristol (England), Rome (Italy), Barcelona (Spain), Munich (Germany), Beijing (China), Moscow (Russia), Buenos Aires (Argentina), Sydney (Australia), and New York (USA); Smart cities World and UK 5G	11
Interviewee-5	New Delhi, Bhopal, and Mumbai (India), Dubai (UAE)	4
Interviewee-6	Jakarta (Indonesia)	1
Interviewee-7	Kuala Lumpur (Malaysia)	5
Interviewee-8	Frankfurt (Germany) and New York (USA); Gartner Consultancy	2
Interviewee-9	Birmingham (England)	1
Interviewee-10	Madrid and Barcelona (Spain); AXPE Consulting	3
Interviewee-11	Jakarta (Indonesia); Qlue Smart City	2
Interviewee-12	Birmingham (England)	1
Interviewee-13	Trento (Italy); EURAC Research	2

Every interview was conducted for a minimum of 30 minutes. An invitation letter with a research information sheet and consent form was sent to the interviewees before the interview meetings could take place. In addition, permission to record the interview was obtained in advance. The interviews were audio-recorded and notes were taken to be used for qualitative data analysis afterward.

The focus of the interview questions was to gather information on the followings datasets:

1) existing approaches used to model the cross-sectoral city processes in the SCD projects and the advantages or disadvantages of these approaches;
2) the requirements and expectations from an ideal CPMo to model the cross-sectoral city processes in the participant's opinion; and

3) the challenges and CSFs asociated with CPMo.

The literature analysis results on findings regarding the BPMo capabilities were analysed and presented in section 4.1. As shown in Figure-1, these findings will be mapped against the interview findings regarding the requirements of CPMo. In addition, the interviewees were also able to provide some information on the current approaches that were being used to plan, control, or monitor progress in the current smart city projects. The findings from this interview section enhanced the literature findings for the first dataset. The second dataset was constructed to identify the requirements of CPMo from the interviewee's perspective to model complex and cross-sectoral city processes (section 4.2.1). Then, the requirements were matched with the capabilities identified in the first dataset to answer the third objective of this research, determining if an existing BPMo on its own or in combination with other tools/techniques/languages can fulfil the requirements for CPMo or an innovative BPMo technique framework needs to be developed (section 5). The interviewees were also enquired about the challenges and CSFs of CMPo, as the third dataset.

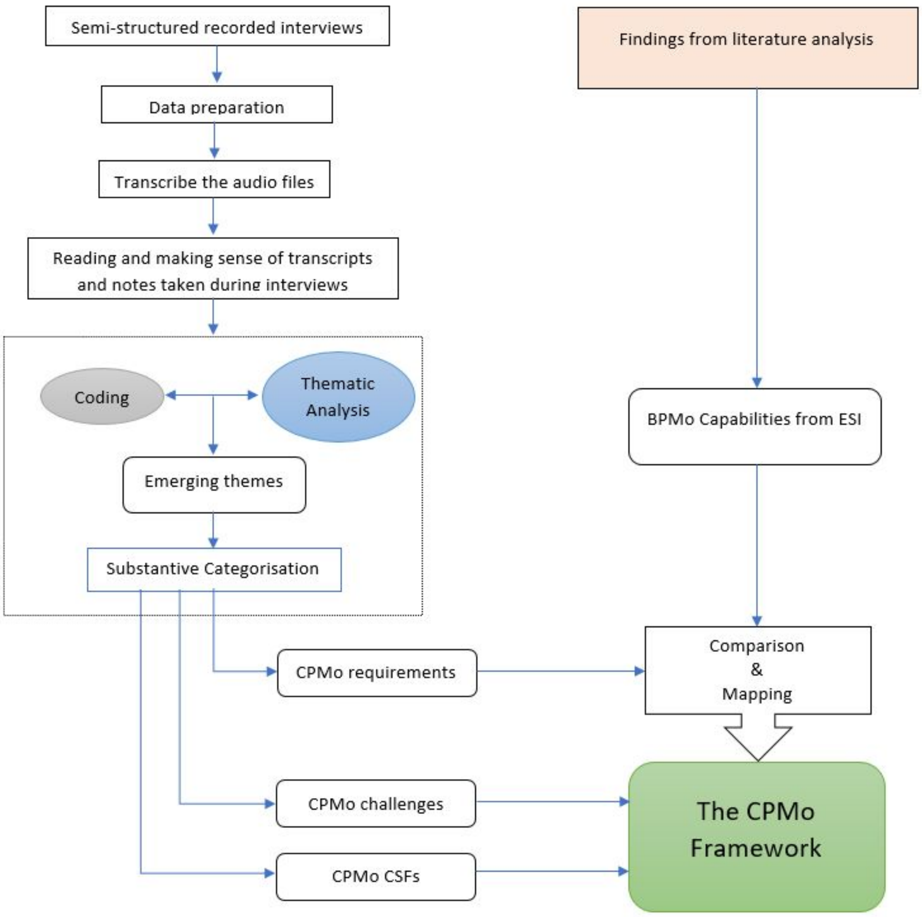

Figure-1: The research analysis design

To analyse the primary data, the interview records were firstly prepared, transcribed, and each transcription was assigned a code instead of interviewees' names to ensure anonymity. In addition, the transcriptions were verified by another colleague for authenticity and data integrity. The notes taken during the interviews were also read and organised to be analysed along with the audio transcriptions. Then, the data was analysed qualitatively to develop themes (Flick, 2013). There was no software used for this purpose and as shown in figure-2, the content was manually analysed. Accordingly, to identify the requirement of CPMo, every material was picked, was carefully read, and the relevant areas of the transcripts/notes were highlighted to excerpt the themes. Then, the themes were substantively categorised to generate a list of topics/categories related to the dataset. Next, similar categories were merged, coded, and utilised to connect related contents. This was carried out for all other material. During the connecting strategy, if a new code were emerged, it was also compared with the existing codes and connected to the related contents. The analysis was repeated to identify CPMo challenges and CSFs to be utilised for further development of the CPMo framework.

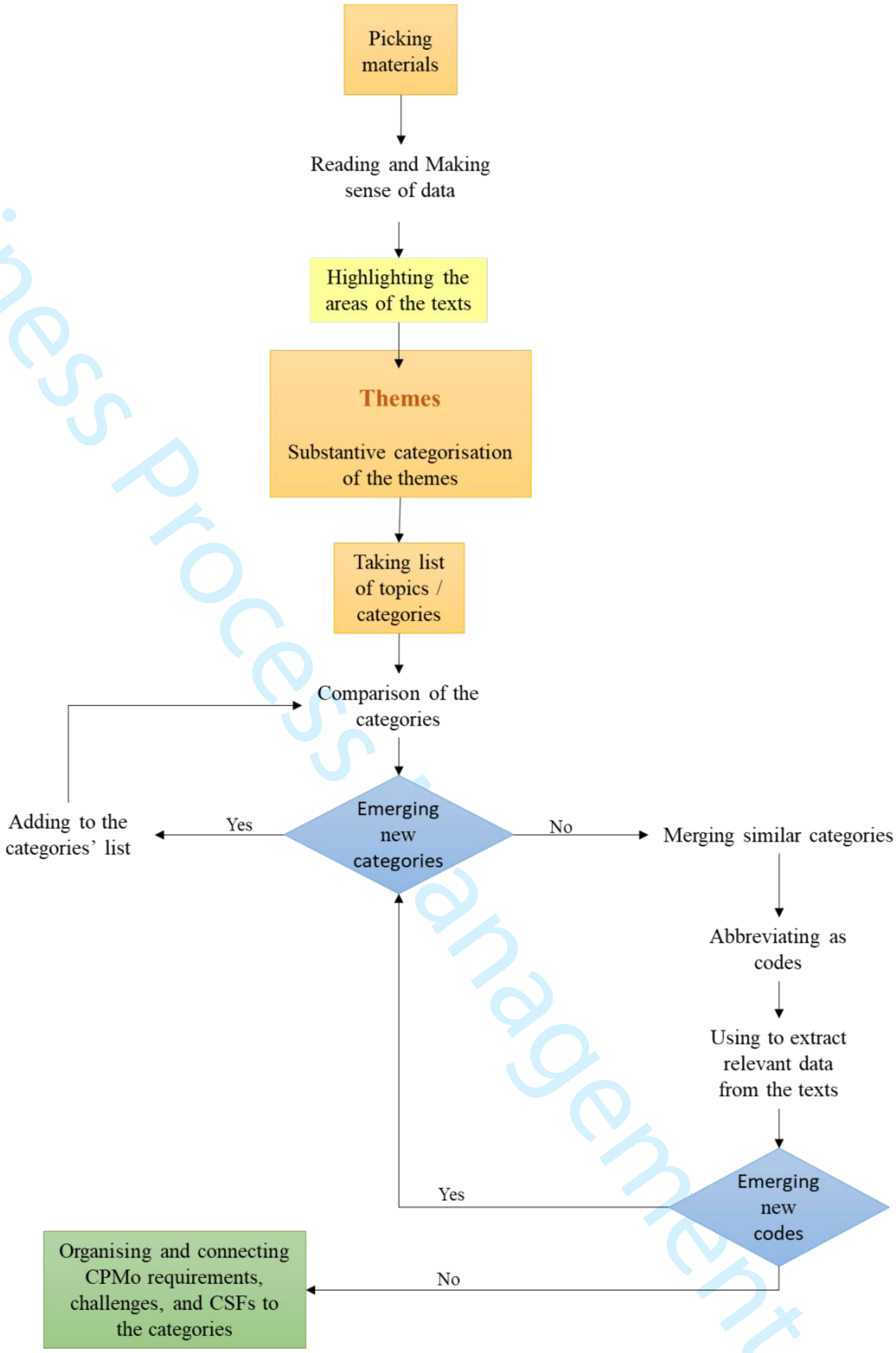

Figure-2: Thematic analysis to identify CPMo requirements, challenges, and success factors

When all three datasets (as shown in Figure-1 and 2) were fully identified and the first dataset was compared with and mapped against the capabilities of existing BPMo ~~tools/techniques~~approaches in the private sector, the results were discussed and applied to develop the CPMo framework of this research.

4. Research findings

The findings of this research from secondary and primary sources will be presented in the following two section:

4.1 Findings from literature analysis

A smart city is considered as an integrated enterprise, due to the level of similarity in the requirements of systems integration between them. In order to identify the required modelling capabilities of existing BPMo for SCD purposes, it was necessary to research those capabilities in the ESI context by identifying broad level similarities between the two. In a complex enterprise, there are multiple departments, multiple levels of hierarchy, stakeholders, and other complexities, especially in business processes (Momoh et al., 2010; Javidroozi et al., 2014, 2019). In the ESI context, organisations at Capability Maturity Model (CMM) level 3 and 4 have performed BPMo for continuous business improvement and/or organisational re-design for efficiency purposes (CMM level 3 - where processes are organised and redesigned at the enterprise level and CMM level 4 - processes are measured and managed systematically) (Wangenheim et al., 2010; Peldzius et al., 2011). For this reason, it was necessary to identify the capabilities, which are relevant to the ESI perspective as these are very similar in nature and thus would closely relate to the requirements necessary in the SCD perspective. Most cited BPMo tools/techniques/languages that have been used in ESI are as follows:

Flow Charts (Asq, 2019), Integrated Definition for Function Modelling (IDEF), Data flow diagrams, Coloured Petri Nets (CPN) (Mohammadi and Mukhtar, 2012), XML Formats(Coleman, 2013), Role-Activity Diagrams (Subhiyakto and Astuti, 2019), UML Activity Diagrams (Birkmeier et al., 2010), BPL4WS (Business Process Execution Language for Web services) (Jacobsen et al., 2010), Event-Driven Process Chains (EPC) (Karhof et al., 2016), Business Process Modelling Notation (BPMN) (OMG, 2020).

The significant capabilities of these BPMo approachestechniques as discussed in the literature have been presented in Table-2.

Table-2: BPMo capabilities from the literature

BPMo capabilities	References
To create simple and complex (nested) models of processes	Aldin and De Cesare, 2009; Harmon and Wolf, 2011; Scheuerlein et al., 2012; Abdel-Fattah et.al., 2017; Subhiyakto and Astuti, 2019

To define the scope of data requirements	Aldin and De Cesare, 2009; Harmon and Wolf, 2011; Scheuerlein et al., 2012; Medoh and Telukdarie, 2017
To store information about roles, costs and other data associated with activities	Harmon and Wolf, 2011; Scheuerlein et al., 2012; Abdel-Fattah et.al., 2017; Subhiyakto and Astuti, 2019
To perform simulation and analytics support	Aldin and De Cesare, 2009; Harmon and Wolf, 2011; Abdel-Fattah et.al., 2017
To store models and processes in a data repository	Harmon and Wolf, 2011; Scheuerlein et al., 2012
To specify constraints such as deadlines	Harmon and Wolf, 2011
To test the solution including user acceptance testing	Harmon and Wolf, 2011; Scheuerlein et al., 2012
To design training	Harmon and Wolf, 2011; Scheuerlein et al., 2012; Abdel-Fattah et.al., 2017; Medoh and Telukdarie, 2017
Technical capabilities: - Ability to post models to the web - Ability to move models to software code - Ability to print models - Support for a standard notation or modelling language	Aldin and De Cesare, 2009; Harmon and Wolf, 2011; Scheuerlein et al., 2012; Abdel-Fattah et.al., 2017; Medoh and Telukdarie, 2017

In addition to the above, there is no one size BPMo approach fits all types of business processes, so that selection of the most appropriate approach for any context is a significant task that need to be carried out by considering various factors, challenges, and dimensions of that particular context (Lederer et al., 2020; Trauer et al., 2021). I~~i~~n the evaluation of BPMo approaches~~tools~~ according to Moody's criteria (Johansson et al., 2012), BPMN scored better over Flowcharts, IDEF, UML, and EPC, based on the following criteria: discriminability, perceptual and cognitive limits, emphasis, cognitive integration, perceptual directness, structure, identification, expressiveness, and simplicity. Although BPMN has most of the capabilities required for process modelling, the following limitations of BPMN in the ESI context must be considered (Smartsheet, 2019):

- Potential mistakes in the modelling elements, due to connectivity or errors in decision making;

- Incorrect modelling can result in the obscurity of process flows, also complex processes require considerable time for modelling, thus resulting in cost increase;
- Effective BPMN implementation requires the stakeholders to possess a higher degree of technical expertise, lack of which can make the communication process daunting and ineffective;
- Representation of complex organisational structures, resources, and strategy can be challenging with projects involving multiple organisations and interconnected processes; and
- Ability to represent complex, interconnected data and information models and functional breakdowns to the lowest levels.

4.2 Findings from primary research

Information about the research participants and the evaluation of data from the primary research has been presented in the methodology section (Table-1). The interviewees were involved in the SCD projects through their own organisation, in the roles of consultants, government officials, or solution providers of smart city solutions. Some of them had worked across multiple organisations, multiple cities, and multiple continents; hence, they could offer a vast experience spanning multiple cities when responding to the interview questions. Accordingly, various data sets from every interviewee with multiple city experience were organised. Thus, it can be concluded that by conducting 13 interviews, CPMo requirements were identified from more than 29 cities in 13 countries, and 8 smart city companies.

The approach~~techniqu~~es used in SCD projects during stages of initial planning, ~~monitoring~~monitoring, and implementation as identified by the research participants have been listed in Table 3.

Table-3: Approaches used for modelling and changing city processes during SCD projects

Approaches
BPMo techniques, such as Flowcharts, BPMN, MS Visio
Microsoft Project Management tools
Smart city frameworks, such as PAS 181, Smart city benchmark model, Smart city maturity model, Citi scope
Microsoft ICT Tools
ERP Planning tools and packages
Value Chain Diagrams
Soft Systems Methodology, AGILE, Scrum, JIRA

As stated by some interviewees, some advantages with Flowcharts, such as simplicity, ease of addition/removal of processes, as well as some limitations for process mapping were identified (Incomplete visualisation, Inefficient information capture from organisational silos), which are significant from SCD perspective.

In addition, interviewee-9 commented that;

> "BPMN and Visio although have good process mapping capabilities for individual projects, they lack visibility (interconnectedness of processes) between projects, which is a significant limitation."

During the interviews, the usage of some other approaches,tools such as Microsoft Projects and smart city frameworks were also mentioned by the interviewees, but it was identified that these approachestools do not have process modelling capabilities and hence are unsuitable for CPMo purposes (interviewees 5, 7, 11, and 13).

For example, interviewee 5 said:

> "We used the value chain diagram, and then ERP. It can be used for business units, they have to be modified. We also use workflow diagram, we use MS Project also, MS Professional for programme management..."

As discussed by several interviewees (1, 4, 10, 13), it was concluded that the concept of CPMo for SCD is still relatively new. The majority of approachestools used in the SCD projects are being used for project management purposes and software development lifecycle projects.

Although it was evident from the discussions that increasingly the respective city councils are exploring the concept of systems integration for SCD, from three interviews, it was also discovered that most of these SCD projects are essentially implemented with the purpose of achieving efficiency gains in a department or to resolve targeted urban problems, such as flood management, waste management or traffic flow management (Interviewees 3, 9, and 12).

4.2.1 CPMo Requirements from Primary Research

The participants were asked to identify the capabilities and requirements of the ideal CPMo for modelling complex cross-sectoral city processes, concerning the city's legislation needs, stakeholder needs, and others. For instance, interview 3 commented:

> "Interoperability on a technical level is important and often there are barriers such as social, legislative etc… I think having some sort of easy to use data repositories, for instance if you are looking at a software tool and it's going to have 10 inputs in terms of datasets, when people still are using spreadsheets and stuff like that and the tech people are putting them into a data repository and what you find is there is not much available that actually allows you at the design level to actually kind of do things in the way I would like to be done really. Yeah so something around process mapping I think and dynamically change inputs and outputs really. If that makes sense."

Interviewee 10 said:

"action lines, which are the costs, results and which are the benefits, where are the interrelations, and all kinds of connections between objectives, tasks, processes, stakeholders, etc. it will be nice for the project manager to show KPI's in a very visual way to the stakeholders, something more visual and something easier."

A summary of these requirements have been listed in Table-4.

Table-4: Requirements of CPMo for SCD (interview findings)

CPMo Requirements	Interviewees
Ability to model complex processes representing interdependencies between multiple processes, departments & stakeholders	1, 9, 10
Ability to represent interconnectivities among cross-sectoral sub-processes	9, 10
Allow multiple inputs from multiple stakeholders	1, 9, 10
Allow cross-sectoral stakeholder collaboration in process mapping	1, 9, 10
Allows to dynamically change inputs and outputs	3
Allows to link process maps directly to the project requirements	9
Addresses the data related challenges	1, 3, 4, 7, 8, 9
Addresses city's interoperability needs	1, 2, 3, 4, 5, 8, 9, 10, 11, 13
Addresses Security requirement	8
Visualisation of cross-sectoral process flows to resolve potential cross-sectoral legislation conflicts	1, 9, 10
Visualisation of End to end process maps to multiple stakeholders to allow decision making	1, 9, 10, 11, 12
KPI's visualisation and realisation	3, 5, 6, 7, 8, 10, 13
Visualisation of costs/benefit/action lines	10, 13
Visualisation of cross sectoral regulations	1
Visibility of impact on multiple stakeholder	9, 10
Visibility of impact on process flows due to departmental legislation	1
Visual representation of project milestones	3

4.2.2 Challenges and Critical Success Factors for City Process Modelling

During the interviews, the participants were asked to reflect upon the challenges of CPMo and the current approaches that were being used. They discussed the different types of challenges and issues that were encountered by the multiple stakeholders when the processes were mapped or explored for improvements (Table-5). They considered these as a kind of process modelling. The ideal CPMo should address or resolve these challenges, in order to successfully model the complex cross-sectoral city processes.

Table-5: Challenges encountered during city process modelling (interview findings)

Challenges during CPMo
People related challenges (skills, change management, clarity of vision)
IT related challenges (varying levels of technical infrastructure in different sectors)
Information capture from organisational silos
Inefficient process captures due to organisational complexity
Non-standardisation of existing processes
Stakeholder collaboration needs

Data challenges with ownership, complexity, data compatibility, security, and privacy
City council challenges with legislation, bureaucracy, and regulation

The majority of the participants could verify that from the current set of approache~~method~~s that were being used in SCD projects in the participant's own organisation, no single tool,~~ or ~~technique, or language could address the challenges of CPMo. The existing tools/techniques/languages in the participant's opinion failed to meet the project management needs, cross-sectoral collaboration needs, or address the city's interoperability needs.

In addition, when interviewees were asked about the success factors for the above-mentioned challenges, the following CSFs for modelling the cross-sectoral city processes were identified (Table-6).

Table-6: CSFs for addressing possible challenges during CPMo (interview findings)

CPMo Requirements	Interviewees
Clarity of shared vision and goals for successful future state visualisation	1, 3, 4, 5, 6, 7, 8, 10, 12
Citizen participation in data gathering - required for data availability requirement for the smart city project	6, 7, 8, 10, 11, 12
Adequate IT infrastructure	6, 13
Stakeholder identification, communication, engagement commitment, and management (cross sectoral, multiple service providers)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
Selection of ideal tool for accurate process capture	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12
Cross sectoral project collaboration	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
Appropriate Information and Requirements gathering methodology	1, 5, 7, 8, 9, 10, 12
Availability of skilled workforce	2, 3, 8, 10, 11, 13
Identification of mandates of stakeholders and identification of how the mandates intersect each other	5

During the interviews, it was mentioned on a singular occasion (interviewee 7) that having an exclusive technology-led approach for developing smart cities is a leading cause of failures for SCD projects. Although not being repeated by other participants during discussions, it is significant due to the reason that 'inclusive cross-sectoral stakeholder participation' has been the most cited requirement for successful CPMo. Moreover, as every city council has its own regulation and every sector has its own legislation framework, to enable cross-sectoral collaboration, overlaps in these areas will need to be identified during the modelling stage.

5. Discussion of the findings to design a framework for developing CPMo approaches

From the literature analysis and primary research, we have obtained the following two components:

Capabilities- These are the main capabilities of existing BPMo tools,~~ and~~ techniques, and languages from the literature (identified in 4.1).

Requirements- These are the expectations of the stakeholders and the ideal requirements, which the CPMo should address to be able to model the cross-sectoral processes for SCD (identified in 4.2.1). Similar requirements in terms of the meanings were grouped together.

To develop a framework for developing CPMo, these two components from Table-2 and Table-4 are mapped with each other to find out if the existing capabilities are matched with the expected requirements (Figure-~~2~~3). If so, then it could have been concluded that a singular or a combination of existing BPMo was adequate to fulfil the research aim and thus, answer the research question. If not, what other elements are required to develop an appropriate CPMo approach~~tool/technique~~.

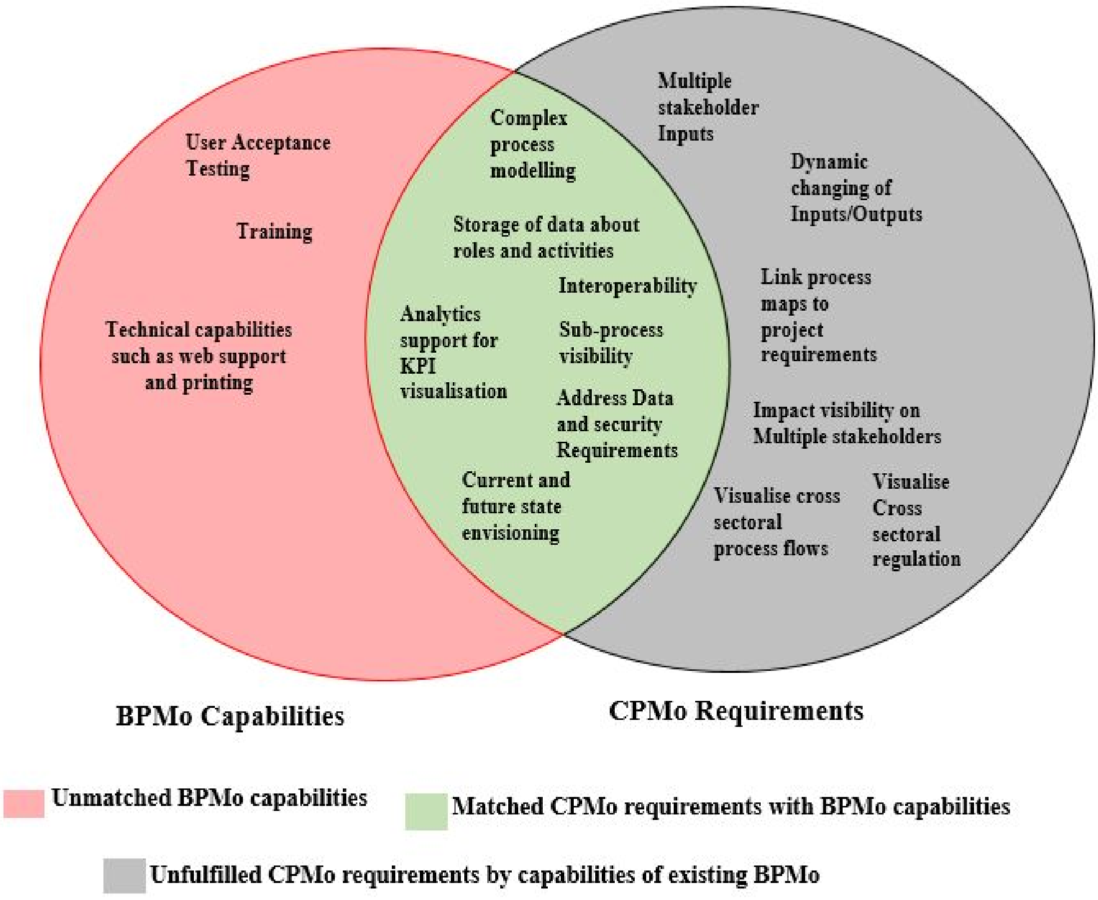

Figure-3~~2~~: Mapping of BPMo Capabilities with Requirements of CPMo

Although the technical capabilities of BPMo (such as the ability to print models, post models on the web, address training capabilities and user testing) did not have an equivalent CPMo requirement need, they can still be considered as implied requirements, because an effective CPMo is needed to have these technical features.

As shown in Figure-3~~2~~, the capabilities of existing BPMo tools, techniques, and languages cannot fully address all of the CPMo requirements for SCD, on their own or in combination, as too many requirements are left unfulfilled by the existing capabilities. Thus, it can also be confirmed that although

BPMN has the most capabilities to address the technical requirements in terms of the ability to model complex processes and sub-processes, it lacks the other requirements, such as the ability to represent regulatory element. Moreover, different city service authorities are governed by their own regulatory framework, hence regulatory constraints governing the individual authorities must be considered during process modelling. These findings verify that no singular BPMo tool, ~~or~~ technique, language, or a combination of them ~~existing tools or technique~~ is suitable to fully address the needs of cross-sectoral process modelling for the purpose of SCD.

Hence, it will be necessary to develop an innovative ~~CPMo framework~~CPMo framework for SCD. This will be carried out by using the unfulfilled requirements of existing BPMo capabilities. In addition, the challenges and CSFs identified in 4.2.2 bring additional dimensions to develop this ~~innovative framework~~innovative framework. Figure-~~3~~4 presents the CPMo framework that acts as a guide to develop a CPMo ~~technique/tool~~approach. Components of this framework have been identified from the unfulfilled CPMo requirements, which are necessary for SCD. Also, the challenges and CSFs as identified from the primary research have provided additional dimensions for the framework.

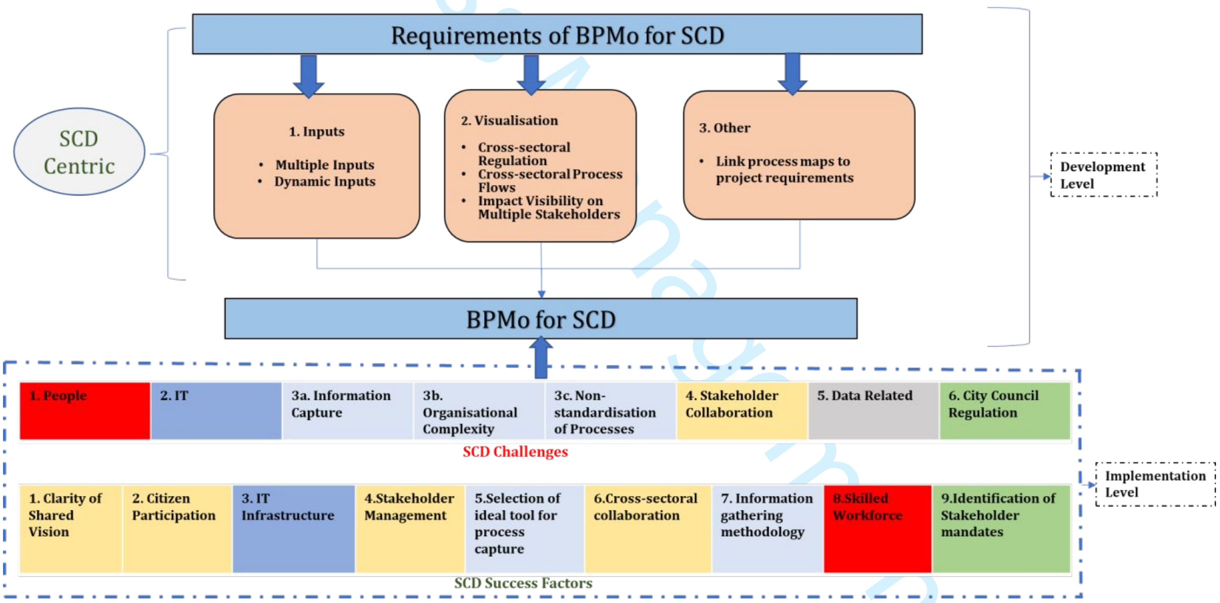

Figure-~~3~~4: A framework for developing CPMo approach~~tools/techniques~~

As shown in the framework, the critical unmet requirements are further grouped into "input", "visualisation", "other" requirements from BPMo. The ability of BPMo to accept multiple inputs and dynamically changing inputs as the project requirements change was cited as being extremely important. Another significant requirement was related to the visualisation aspect of the BPMo, namely the visualisation of cross-sectoral regulation in the process modelling e.g. the impact of data regulation on collaboration projects between city service providers, such as NHS and Transport. It was also necessary to visualise the impact of process change on multiple stakeholders as a result of the SCD initiative. Another BPMo requirement was the ability to link process maps to project requirements. These requirements are SCD centric and will need to be addressed during the development level.

At the implementation level, the challenges encountered during CPMo will need to be addressed as well. The challenges identified in the primary research were further grouped together based on the similarities of their context. Success factors that can resolve these challenges were colour coded in the figure and have been explained below:

1. People related challenges, which can be addressed by several success factors, such as ensuring the availability of skilled workforce before the implementation of SCD projects;
2. IT challenges: availability of adequate infrastructure to ensure successful implementation post modelling;
3. Information capture from organisational silos, organisational complexity and non-standardisation of processes: city service authorities are organisationally complex and usage of thea most appropriate information gathering methodology and selection of an ideal approach tool for accurate process capture can address these challenges related to process modelling;
4. Stakeholder collaboration: to resolve this challenges, it will be necessary to perform extensive stakeholder management, consisting of cross-sectoral stakeholder identification, relevant to the smart city initiatives. This has been cited as a success factor by almost all research participants. Clarity of shared vision and citizen participation with comprehensive communication and engagement plans are necessary to ensure continuous engagement and commitment to SCD initiative. Hence, co-ordination between these stakeholder groups is extremely important for successful city process modelling;
5. Data related challenges: data is stored in different formats across different city services and it will be necessary to resolve this challenge at implementation level;
6. City council regulation challenges: as identified from the primary research, the regulation differs considerably between different cities and local administrative bodies. Also, the service providers have their own legal framework. Hence identification of overlaps and conflicts in the early stages is important. The BPMo developers will need to consider regulation as an input, along with identification of stakeholder mandates which will help resolve potential conflicts in cross-sectoral process mapping.

5.1 Positioning the CPMo framework in the body of knowledge

The CPMo framework, developed in this study can be positioned in several areas, in order to add value to the existing smart city related frameworks. ~~Some examples are listed as follows:~~

- In the four stages of the smart city framework based on the BPR principles (Budhiputra and Putra, 2016), namely identification of citizen's problems, business process assessment, developing use case and identification of vertical solutions and solution implementation, there is a requirement of tools at every step in order to achieve business process standardisation. The new CPMo will enable identification of the bottlenecks in the current systems and help to achieve business process standardisation which is an operational motivation driver and in fact a goal of any change of business processes, as well as the end vision of this framework (Al-Mashari et al., 2003; Davenport et al., 2004).~~;~~

- The CPMo framework developed in this study can provide a modelling dimension to the input component of the Smart City Initiatives Design (SCID) Framework (Ojo et al., 2015), thus helping to explore its usability in terms of practical application.~~;~~

- In the smart city landscape model (Jamous and Hart, 2019), the CPMo framework can enable the interconnection of its components, which are smart energy, smart logistics, smart traffic management and smart places, all linked using Point to Point (P2P) approach.~~;~~

- In the Smart Asset Alignment to Citizen Requirements Framework (SAACRF) proposed by Heaton and Parlikad (2019) the alignment of the city's services according to citizen's needs has been proposed. The data model integration layer between the services and citizens requirements aims to address the interoperability needs but it lacks any discussion about process modelling, which is needed to enable this transformation. The CPMo framework can provide the missing dimension to this framework with impact visualisation on multiple stakeholders with systems integration.~~;~~

- A data analytics-based framework proposed by Puiu et al. (2016), which aims to collect raw data from multiple sources in the city and convert it into actionable information, thus helping to create insightful smart city applications, provides integration of heterogeneous data streams, providing interoperability, quality analysis, and real-time data analytics and application development. Using the CPMo framework, developed in this study can be useful in the practical implementation of the Puiu et al.'s framework, as it will address the process modelling requirement which is needed in the development phase.~~;~~

- The generic SCD framework (BSI, 2015) is built on the concept of integration of physical, human and digital systems with a view to delivering a sustainable smart city (BSI, 2014) and thus supports the underlying foundation of a smart city from an ESI perspective. This framework is intended to be used to set a smart city strategy for the urban policymakers and city governments, so although it addresses the 'What' element as in, 'what does a city need to be smart?, it does not address the 'how' (i.e. the methodology required to enable the transformation). Hence, the CPMo framework of this research can be used with the SCFs as it will fulfil the criteria *[B] cross-city governance and delivery processes*. Specifically *[B2] Transforming the city's operating model* by enabling BPC for SCD can be achieved by using the CPMo framework to model the complex cross-sectoral city processes. ~~;~~

The CPMo framework can also provide the dimension of intercity process modelling to the SC model which is based on a business model canvas (Giourka et al., 2019). The original smart city model does not address the roadmap to achieve this transformation and does not identify the challenges associated with this process. Using the CPMo framework will provide the missing dimension and helps to validate the value proposition of this smart city model.

~~-~~ ~~;~~

The smart city framework proposed by Pettit et al. (2018) defines a smart city as one that is built on the overlapping dimensions of culture, metabolism and governance. The authors define metabolism as the element that enables the introduction of new technology in the city to address the city's problems (traffic, recycling, etc.) while improving liveability and the city's economic performance. The CPMo framework can address the integration requirement of this framework thus proposing its usefulness for practical implementation for SCD.

~~-~~ ~~;~~

- To address shared infrastructure and challenges (Chorabi et al., 2012) in a smart city, it is necessary to have cross-sectoral collaboration and interoperability of systems. Interoperability is the ability of systems to share data and turn information into action without any access, implementation or usage constraint (Minetti, 2020). Modelling the processes as they flow through the legacy systems will enable the solutions developers to address the interoperability requirement which is necessary for systems integration for the purpose of SCD. The frameworks discussed in this section fail to address the city's interoperability and system integration requirements on their own. Using the innovative CPMo framework of this study in conjunction with these frameworks will add this missing dimension to enable development of smart cities.

6. Conclusions

To transform a city into a smart city, there is a need to integrate complex sub-systems and change legacy cross-sectoral city processes. Systems integration in the private sector requires BPC as an essential part of it. To achieve BPC, there are many BPMo approaches, utilised by various tools, ~~and~~ techniques, and languages available. The focus of this research was to identify the most appropriate BPMo approach ~~technique~~ for the purpose of SCD (CPMo). Current literature was analysed to identify if any of the existing modelling approaches~~tools/techniques~~ in ESI on its own or in combination with others were suitable to achieve this purpose. Literature analysis revealed that there was a significant lack of discussion on this topic; as such, the research gap was confirmed. In order to answer the research question, the research methodology was designed to gather data from primary research. The research participants were interviewed remotely, and questions were formulated to derive insights from their experience on having been involved in changing and modelling cross-sectoral city processes for SCD projects. The data was qualitatively analysed to identify the current capabilities of existing BPMo tools/techniques/languages and map them with CPMo requirements in the SCD context. The results of this mapping indicated that not all CPMo requirements were fulfilled from current BPMo capabilities. Therefore, the main components of CPMo framework (the outcome of this research) were established. In addition, based on the qualitative data analysis, the challenges encountered during CPMo and the critical success factors added additional dimensions, which will prove useful in the implementation stage of this framework. Hence, the CPMo framework was fully developed to act as a guide for developing CPMo approachestools/techniques for SCD purposes.

6.1 Research contributions

Yet, the city councils' approach towards attaining a smart city vision has been to deploy point solutions developed by technical solution providers to solve specific problems in a city. In addition, as discussed in this research, current smart city roadmaps, and assessment frameworks lack the process change and modelling elements, which are necessary to achieve SCD. This research attempted to address these deficiencies by developing a CPMo framework, which can also compliment the existing SCD frameworks (as discussed in 5.1). In summary, the main contributions of this research have been categorised into the following two categories:

1. Practical contributions:

- —The innovative CPMo framework developed in this research fills the gap posed by existing SCD frameworks by employing a step by step approach to help make the transition from the current state to future state of SCD, especially from city systems integration viewpoint. ;

- —in addition, Tthis framework endeavours to provide a guideline for smart city solution providers to develop new tools/techniques/languages for CPMo. ;

- —The framework also guides city authorities and smart city developers to build/improve their SCD roadmap, through providing an insight regarding the necessity of considering cross-sectoral city systems integration, BPC, and CPMo, when developing their roadmap. ;

- Moreover, Tthe framework helps smart city developers to better understand the challenges that can be faced during cross-sectoral city systems integration and city process change and enhances their capabilities to address those challenges. .

2. Theoretical contributions:

- ~~–~~This research proved that developing an appropriate CPMo approach~~technique~~ for SCD is necessary, since none of the current BPMo ~~tools, techniques, or~~ approaches is fully applicable for cross-sectoral city process change. ~~;~~
- ~~–~~The CPMo framework also contributes in addressing some of the BPC challenges for SCD, such as clarification and understanding, BPC monitoring challenge, standardization, interoperability, agility and flexibility, and interdependencies. ~~;~~
- Furthermore, ~~T~~this research justified that the learnings from ESI can be useful for SCD context, as during this study the ESI learnings were utilised to develop the CPMo framework and to address the challenges involved.

6.2 Research limitations and recommendations for further research

Similar to any other qualitative research the number of participants can be questioned as a limitation of the study. However, in this research, after 10 interviews a saturation point was met, where no new findings regarding the SCD centric requirements of CPMo were recognised. Then, three more interviews were also conducted to confirm the saturation point. In addition, a global geographical range of experts was interviewed to gather opinions from various cities in the world, such as Barcelona, Rome, Jakarta, and Sydney, to ensure the generalisability of the study was met. In addition to this, most of the interviewees were able to utilise their experiences from various sectors, councils, IT companies, and consultancy groups, so that various opinions from different SCD strategies and approaches were utilised in this study. Hence, 13 semi-structured interviews provided sufficient data to achieve the outcome of the research.

~~6.3 Recommendations and further research~~

This study developed a novel CPMo framework to guide smart city developers and solution providers for their future SCD related developments. Therefore, i~~I~~t will be necessary to utilise the CPMo framework for developing tools, ~~and~~ techniques, and languages for modelling cross-sectoral processes for the purpose of SCD. Consequently, the framework can be implemented for a SCD project and changing cross-sectoral city processes among various city sectors, hence ensuring the practical validation of the CPMo framework.

References

Abdel-Fattah, M.A., Khedr, A.E. and Aldeen, Y.N., 2017. An evaluation framework for business process modeling techniques. International Journal of Computer Science and Information Security (IJCSIS), 15(5), pp.382-392

Abu-Shanab, Emad and Bataineh, L. (2015) Challenges facing E-government projects: How to avoid failure, 4, pp. 207-217.

Aldin, L. and De Cesare, S., 2009. A comparative analysis of business process modelling techniques.

Al-Mashari M, Al-Mudimigh A and Zairi M (2003) Enterprise resource planning: A taxonomy of critical factors. *European Journal of Operational Research* 146(2): 352–364.

Angelidou, M., (2017) Smart city planning and development shortcomings. TeMA-Journal of Land Use, Mobility and Environment, 10(1), pp.77-94.

Anthopoulos L and Giannakidis G (2017) Task-based process modeling for policy making in smart cities. *Proceedings of the 2016 ITU Kaleidoscope Academic Conference: ICTs for a Sustainable World, ITU WT 2016*. Institute of Electrical and Electronics Engineers Inc. DOI: 10.1109/ITU-WT.2016.7805707.

Asq (2019). What is a Flowchart? Process Flow Diagrams & Maps | ASQ. [online] Available at: https://asq.org/quality-resources/flowchart.

Bandara W, Gable GG, Tate M, et al. (2021) A validated business process modelling success factors model. *Business Process Management Journal* 27(5). Emerald Publishing Limited: 1522–1544. DOI: 10.1108/BPMJ-06-2019-0241.

Beauchamp, G. (2020) Why & How: Business Process Modelling - Business Analyst Community & Resources | Modern Analyst. [online] www.modernanalyst.com. Available at: https://www.modernanalyst.com/Resources/Articles/tabid/115/ID/864/Why-How-Business-Process-Modelling.aspx.

Birkmeier, D.Q., Kloeckner, S. and Overhage, S. (2010) An empirical comparison of the usability of BPMN and UML activity diagrams for business users.

BSI. (2014) Code of practice for Smart city framework: Guide to establishing strategies for smart cities and communities. [SOURCE: PAS 180:2014, 3.1.62]

BSI (2015). PAS:181 – Smart Cities Framework | BSI Group. [online] Available at: https://www.bsigroup.com/en-GB/smart-cities/Smart-Cities-Standards-and-Publication/PAS-181-smart-cities-framework/.

Budhiputra, P., M. & Putra, K., P. (2016) "Smart city framework based on business process re-engineering approach", IEEE, pp. 69.

Bhaskar, H., L. (2018) Business process reengineering framework and methodology: a critical study. International Journal of Services and Operations Management, 29(4), p.527.

Chen, Y., T. and Wang, M., S. (2017) A study of extending BPMN to integrate IoT applications, International Conference on Applied System Innovation (ICASI), Sapporo, Japan.

Chourabi, H., et al. (2012) “Understanding Smart Cities: An Integrative Framework,” in 2012 45th Hawaii International Conference on System Sciences, pp. 2289–2297.

Coleman, J. (2013) Data flow sequences: A revision of data flow diagrams for modelling applications using XML. International Journal of Advanced Computer Science and Applications (ijacsa), 4(5), pp.28-31.

Cornesse, C., Blom, A.G., Dutwin, D., Krosnick, J.A., De Leeuw, E.D., Legleye, S., Pasek, J., Pennay, D., Phillips, B., Sakshaug, J.W., Struminskaya, B. and Wenz, A. (2020). A Review of

Conceptual Approaches and Empirical Evidence on Probability and Nonprobability Sample Survey Research. Journal of Survey Statistics and Methodology, 8(1), pp.4–36.

Creswell, J., W. (2015) A concise introduction to mixed methods research, SAGE, Los Angeles

Davenport TH, Harris JG and Cantrell S (2004) Enterprise systems and ongoing process change. *Business Process Management Journal* 10(1). Emerald Group Publishing Limited: 16–26.

DeLusignan, S., Krause, P., Michalakidis, G., Vicente, M.T., Thompson, S., McGilchrist, M., Sullivan, F., van Royen, P., Agreus, L., Desombre, T. and Taweel, A., (2012) Business process modelling is an essential part of a requirements analysis. Yearbook of Medical Informatics, 21(01), pp.34-43.

Finney S and Corbett M (2007) ERP implementation: a compilation and analysis of critical success factors. *Business Process Management Journal* 13(3). Emerald Group Publishing Limited: 329–347.

Flick, U (ed.) (2013) The SAGE Handbook of Qualitative Data Analysis, SAGE Publications, London. Available from: ProQuest Ebook Central.

Forliano C, De Bernardi P, Bertello A, et al. (2020) Innovating business processes in public administrations: towards a systemic approach. *Business Process Management Journal* 26(5). Emerald Publishing Limited: 1203–1224. DOI: 10.1108/BPMJ-12-2019-0498.

Gascó-Hernandez, M., (2018) Building a smart city: lessons from Barcelona. Communications of the ACM, 61(4), pp.50-57.

Giourka, P., Sanders, M.W., Angelakoglou, K., Pramangioulis, D., Nikolopoulos, N., Rakopoulos, D., Tryferidis, A. and Tzovaras, D., 2019. The smart city business model canvas—A smart city business modeling framework and practical tool. Energies, 12(24), p.4798.

Girardi, P. and Temporelli, A., (2017),' Smartainability: a methodology for assessing the sustainability of the smart city'. Energy Procedia, 111(1), pp.810-816.

Harmon P (2003) *Business Process Change: A Manager's Guide to Improving, Redesigning and Automating Processes*. San Francisco: Morgan Kaufmann Publishers.

Harmon, P. and Wolf, C. (2011) Business process modelling survey. Business process trends, 36(1), pp.1-36.

Harmon, P. (2014) Business process change: a business process management guide for managers and process professionals, 3rd edn, Morgan Kaufmann, Amsterdam.

Heaton, J. and Parlikad, A., K. (2019) A conceptual framework for the alignment of infrastructure assets to citizen requirements within a Smart Cities framework. Cities, [online] 90, pp.32–41. Available at: https://www.sciencedirect.com/science/article/pii/S0264275118304384.

Ibrahim, M., El-Zaart, A. & Adams, C. (2018) "Smart sustainable cities roadmap: Readiness for transformation towards urban sustainability", Sustainable cities and society, vol. 37, pp. 530-540.

Jacobsen, H.A., Li, G., and Muthusamy, V. (2010) A distributed service-oriented architecture for business process execution. ACM Transactions on the Web (TWEB), 4(1), pp.1-33.

Jamous, N. and Hart, S.W. (2019) Towards an Integration Concept of Smart Cities. 2019 2nd International Conference on new Trends in Computing Sciences (ICTCS).

Javidroozi, V., Shah, H., Cole, A. and Amini, A. (2014) Smart City as an Integrated Enterprise: A Business Process Centric Framework Addressing Challenges in Systems Integration, pp. 20-24.

Javidroozi, V., Shah, H., Cole, A. and Amini, A. (2015) Towards a City's Systems Integration Model for Smart City Development: A Conceptualization, International Conference on Computational Science and Computational Intelligence (CSCI), pp. 312–317.

Javidroozi V, Shah H and Feldman G (2019) A framework for addressing the challenges of business process change during enterprise systems integration. *Business Process Management Journal* 26(2). Emerald Group Publishing Ltd.: 463–488.

Javidroozi, V., Shah, H. and Feldman, G. (2019) Urban Computing and Smart Cities: Towards Changing City Processes by Applying Enterprise Systems Integration Practices, IEEE Access, 7, pp.108023-108034.

Johansson, L., Wärja, M. & Carlsson, S. (2012) An evaluation of business process model techniques, using Moody's quality criterion for a good diagram.

Karhof, A., Jannaber, S., Riehle, D.M., Thomas, O., Delfmann, P. and Becker, J. (2016) On the de-facto standard of event-driven process chains: reviewing EPC implementations in process modelling tools. Modellierung.

Khan, S.M., Sulgrove, A., Silverberg, R., Loderup, M. and Berst, J. (2017) Smart Cities and Communities GDT Smart City Solutions on Intel ® -based Dell EMC infrastructure.

Komninos, N. and Mora, L., 2018. Exploring the big picture of smart city research. Scienze Regionali, 17(1), pp.15-38.

Knox, S. and Burkard, A. (2009) Qualitative research interviews: Psychotherapy Research, 19(4-5), pp.566-575.

Lederer M, Quitt A, Büsch M, et al. (2020) One size fits all An analytical approach how to make use of process modelling techniques for different fundamental supply chain types. *International Journal of Supply Chain and Operations Resilience* 4(1). Inderscience Publishers: 1. DOI: 10.1504/IJSCOR.2020.105948.

Legner C and Wende K (2007) 'The Challenges of Inter-organizational Business Process Design – a Res' by Christine Legner, et al. In: *European Conference on Information Systems (ECIS 2007)* (eds H Österle, J Schelp, and R Winter), 2007, pp. 1643–1654.

Lom, M. & Pribyl, O. (2020) "Smart city model based on systems theory", International journal of information management, pp. 102092.

Lombardi, P., Giordano, S., Farouh, H. and Yousef, W. (2012) Modelling the smart city performance. Innovation: The European Journal of Social Science Research, 25(2), pp.137-149.

Medoh, C. and Telukdarie, A. (2017) Business process modelling tool selection: A review, IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), Singapore, pp. 524-528.

Mendling, J., Reijers, H.A. and van der Aalst, W.M.P. (2010). Seven process modelling guidelines (7PMG). Information and Software Technology, 52(2), pp.127–136.

Minetti, G. (2020) Creating truly open cities: why interoperability and 6LoWPAN matter. [online] Smart Cities World.

Mohammadi, M. and Mukhtar, M. (2012) Business process modelling languages in designing integrated information system for supply chain management. International Journal on Advanced Science, Engineering and Information Technology, 2(6), pp.464-467.

Momoh A, Roy R and Shehab E (2010) Challenges in enterprise resource planning implementation: state-of-the-art. *Business Process Management Journal* 16(4). Emerald Group Publishing Limited: 537–565. DOI: 10.1108/14637151011065919.

Motwani, J., Mirchandani, D., Madan, M. and Gunasekaran, A. (2002) Successful implementation of ERP projects: evidence from two case studies. International Journal of Production Economics, 75(1-2), pp.83-96.

Nam, T. and Pardo, T. (2011) Conceptualizing smart city with dimensions of technology, people, and institutions, ACM, pp. 282.

Ojo, A., Curry, E., Janowski, T., and Dzhusupova, Z. (2015) "Designing Next Generation Smart City Initiatives: The SCID Framework," in Transforming City Governments for Successful Smart Cities, M. P. Rodríguez-Bolívar (ed.), Cham: Springer International Publishing, pp. 43–67

OMG. (2020) About the Business Process Model and Notation Specification Version 2.0.2. [online] Available at: https://www.omg.org/spec/BPMN/2.0.2/.

Oracle (2020) Fusion Middleware Modeling and Implementation Guide for Oracle Business Process Management. [online] Available at: https://docs.oracle.com/cd/E29542_01/doc.1111/e15176/bp_hwfconf_shared.htm#BPMPD87304.

Osman, A.M.S. (2019) "A novel big data analytics framework for smart cities", Future generation computer systems, vol. 91, pp. 620-633.

Pettit, C., Bakelmun, A., Lieske, S.N., Glackin, S., Thomson, G., Shearer, H., Dia, H. and Newman, P. (2018) Planning support systems for smart cities. City, culture and society, 12, pp.13-24.

Peldzius, S. and Ragaisis, S., 2011. Comparison of maturity levels in CMMI-DEV and ISO/IEC 15504. Applications of Mathematics and Computer Engineering, pp.117-122.

Pereira VR, Maximiano ACA and Diógenes de Souza Bido (2019) Resistance to change in BPM implementation. *Business Process Management Journal* ahead-of-p(ahead-of-print).

Pierce P, Ricciardi F and Zardini A (2017) Smart cities as organizational fields: A framework for mapping sustainability-enabling configurations. *Sustainability (Switzerland)* 9(9). MDPI AG: 1506.

Puiu, D., Barnaghi, P., Tönjes, R., Kümper, D., Ali, M.I., Mileo, A., Parreira, J.X., Fischer, M., Kolozali, S., Farajidavar, N. and Gao, F., (2016) Citypulse: Large scale data analytics framework for smart cities. IEEE Access, 4, pp.1086-1108.

Saluky, S. (2018) Development of enterprise architecture model for smart city. ITEj (Information Technology Engineering Journals), 2(2).

Schaffers H, Komninos N and Pallot M (2012) Smart Cities as Innovation Ecosystems Sustained by the Future Internet. Lyon, France.

Scheuerlein, H., Rauchfuss, F., Dittmar, Y., Molle, R., Lehmann, T., Pienkos, N. and Settmacher, U. (2012). New methods for clinical pathways—Business Process Modeling Notation (BPMN) and Tangible Business Process Modeling (t.BPM). Langenbeck's Archives of Surgery, 397(5), pp.755–761.

Scuotto V, Ferraris A and Bresciani S (2016) Internet of Things: Applications and challenges in smart cities: a case study of IBM smart city projects. Business Process Management Journal 22(2). Emerald Group Publishing Ltd.: 357–367. DOI: 10.1108/BPMJ-05-2015-0074.

Slack N, Chambers S and Johnston R (2009) *Operations and Process Management: Principles and Practice for Strategic Impact*. Prentice Hall/Financial Times.

Smartsheet (2019). Business Process Modeling and Notation (BPMN) 101 | Smartsheet. [online] Available at: https://www.smartsheet.com/beginners-guide-business-process-modeling-and-notation-bpmn.

Subhiyakto, E.R. and Astuti, Y.P. (2019) March. Design and Development Meeting Schedule Management Application using the RAD Method. In 2019 International Conference of Artificial Intelligence and Information Technology (ICAIIT) (pp. 60-64). IEEE.

Tarhini, A., Ammar, H., Tarhini, T. and Masa'deh, R. (2015) Analysis of the Critical Success Factors for Enterprise Resource Planning Implementation from Stakeholders' Perspective: A Systematic Review. International Business Research, 8(4).

Townsend AM (2013) Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia. W. W. Norton & Company. New York: W. W. Norton & Company.

Trauer J, Wöhr F, Eckert C, et al. (2021) CRITERIA FOR SELECTING DESIGN PROCESS MODELLING APPROACHES. *Proceedings of the Design Society* 1. Cambridge University Press: 791–800. DOI: 10.1017/PDS.2021.79.

Wangenheim, von, C.G., Hauck, J.C.R., Salviano, C.F. and von Wangenheim, A. (2010) May. Systematic literature review of software process capability/maturity models. In International Conference on Software Process Improvement and Capability Determiniation–Spice.

Weber, M. and Podnar-Žarko, I. (2019) A Regulatory View on Smart City Services. Sensors (Basel, Switzerland), 19(2).

Westraadt, L. and Calitz, A. (2020) A Modelling Framework for Integrated Smart City Planning and Management. Sustainable Cities and Society, p.102444.

Xu L Da (2011) Enterprise Systems: State-of-the-Art and Future Trends. *IEEE Transactions on Industrial Informatics* 7(4). IEEE: 630–640. DOI: 10.1109/TII.2011.2167156.

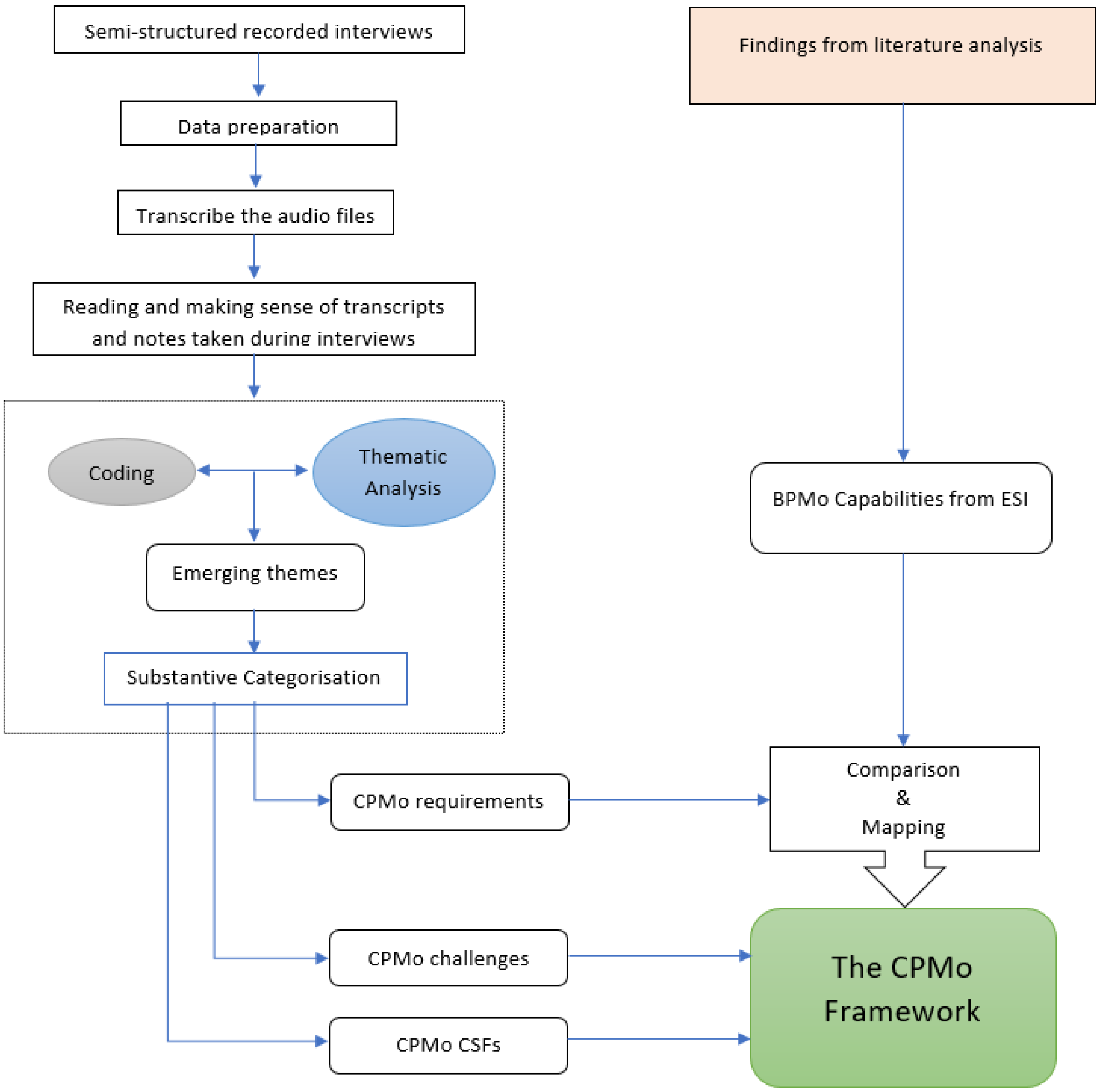

Figure-1: The research analysis design

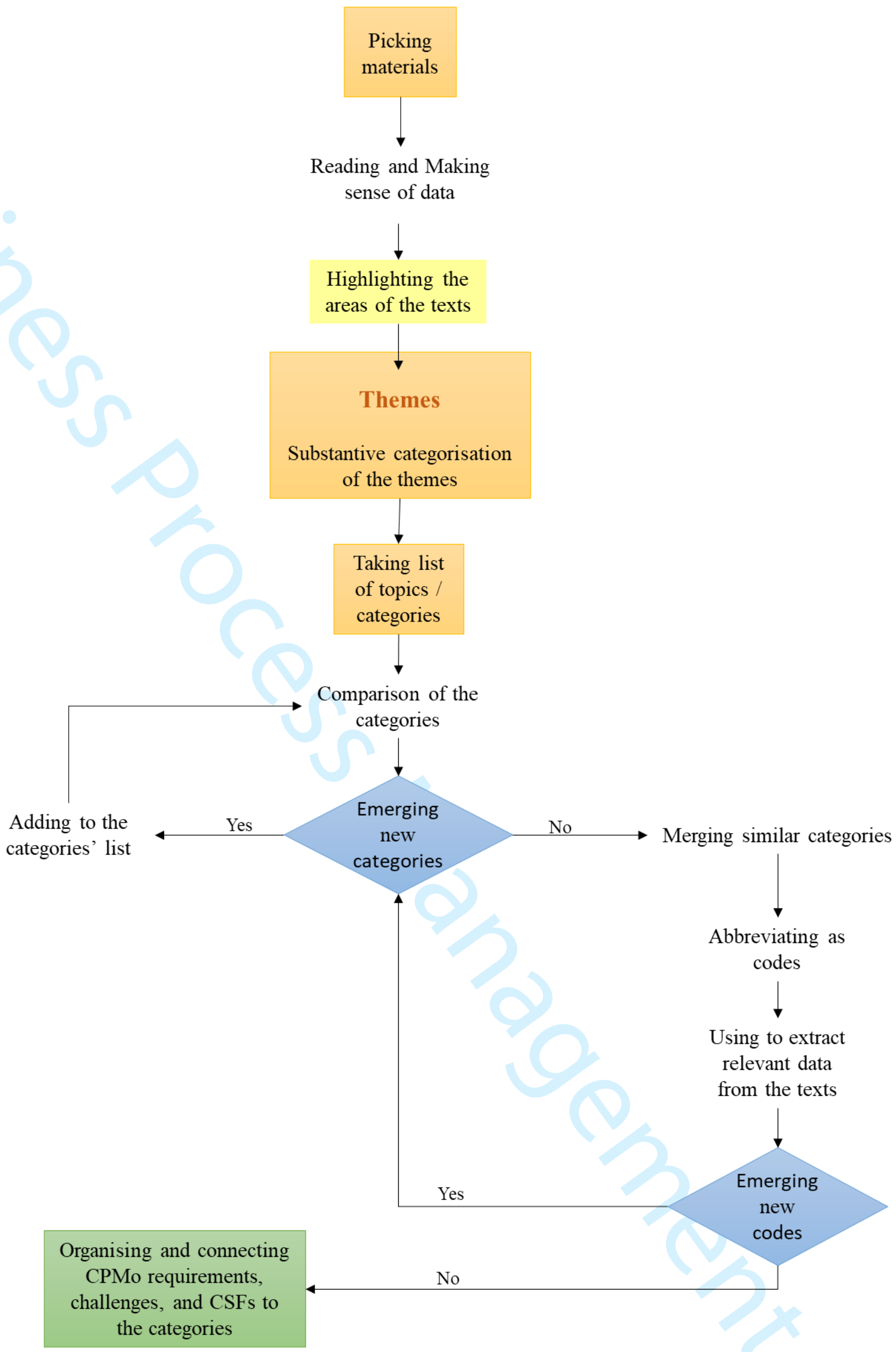

Figure-2: Thematic analysis to identify CPMo requirements, challenges, and success factors

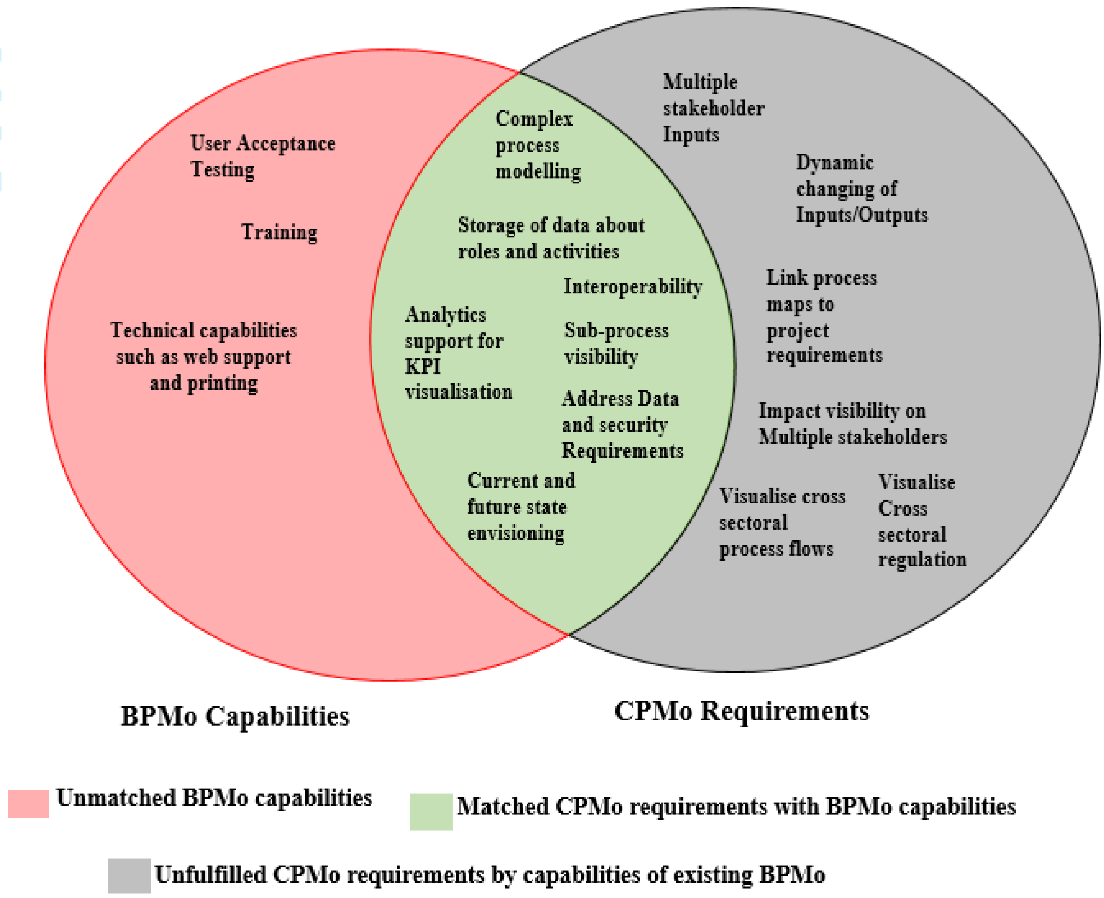

Figure-3: Mapping of BPMo Capabilities with Requirements of CPMo

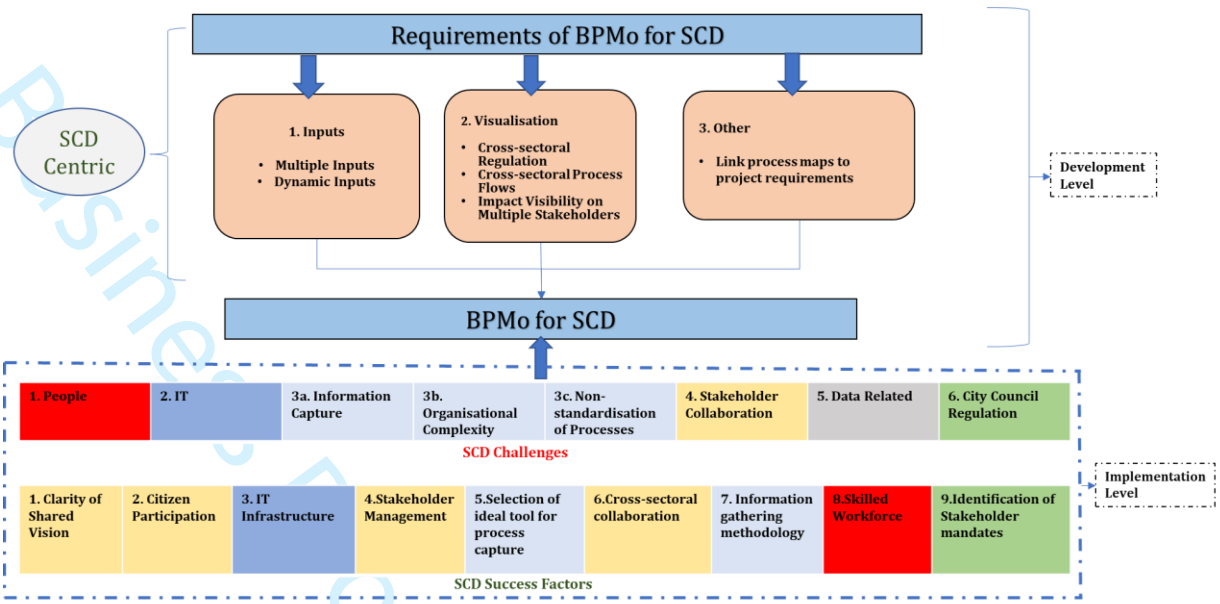

Figure-4: A framework for developing CPMo approach

Table-1: Some information about interviewees

Interviewees	Smart city experiences	Total number of city councils/organisations per interviewee
Interviewee-1	Warwick, Walsall, Birmingham, Wolverhampton (England); TMS Consultancies	5
Interviewee-2	Birmingham (England); Highways England	2
Interviewee-3	Manchester (England)	1
Interviewee-4	Bristol (England), Rome (Italy), Barcelona (Spain), Munich (Germany), Beijing (China), Moscow (Russia), Buenos Aires (Argentina), Sydney (Australia), and New York (USA); Smart cities World and UK 5G	11
Interviewee-5	New Delhi, Bhopal, and Mumbai (India), Dubai (UAE)	4
Interviewee-6	Jakarta (Indonesia)	1
Interviewee-7	Kuala Lumpur (Malaysia)	5
Interviewee-8	Frankfurt (Germany) and New York (USA); Gartner Consultancy	2
Interviewee-9	Birmingham (England)	1
Interviewee-10	Madrid and Barcelona (Spain); AXPE Consulting	3
Interviewee-11	Jakarta (Indonesia); Qlue Smart City	2
Interviewee-12	Birmingham (England)	1
Interviewee-13	Trento (Italy); EURAC Research	2

Table-2: BPMo capabilities from the literature

BPMo capabilities	References
To create simple and complex (nested) models of processes	Aldin and De Cesare, 2009; Harmon and Wolf, 2011; Scheuerlein et al., 2012; Abdel-Fattah et.al., 2017; Subhiyakto and Astuti, 2019
To define the scope of data requirements	Aldin and De Cesare, 2009; Harmon and Wolf, 2011; Scheuerlein et al., 2012; Medoh and Telukdarie, 2017
To store information about roles, costs and other data associated with activities	Harmon and Wolf, 2011; Scheuerlein et al., 2012; Abdel-Fattah et.al., 2017; Subhiyakto and Astuti, 2019
To perform simulation and analytics support	Aldin and De Cesare, 2009; Harmon and Wolf, 2011; Abdel-Fattah et.al., 2017
To store models and processes in a data repository	Harmon and Wolf, 2011; Scheuerlein et al., 2012
To specify constraints such as deadlines	Harmon and Wolf, 2011
To test the solution including user acceptance testing	Harmon and Wolf, 2011; Scheuerlein et al., 2012
To design training	Harmon and Wolf, 2011; Scheuerlein et al., 2012; Abdel-Fattah et.al., 2017; Medoh and Telukdarie, 2017
Technical capabilities: - Ability to post models to the web - Ability to move models to software code - Ability to print models - Support for a standard notation or modelling language	Aldin and De Cesare, 2009; Harmon and Wolf, 2011; Scheuerlein et al., 2012; Abdel-Fattah et.al., 2017; Medoh and Telukdarie, 2017

Table-3: Approaches used for modelling and changing city processes during SCD projects

Approaches
BPMo techniques, such as Flowcharts, BPMN, MS Visio
Microsoft Project Management tools
Smart city frameworks, such as PAS 181, Smart city benchmark model, Smart city maturity model, Citi scope
Microsoft ICT Tools
ERP Planning tools and packages
Value Chain Diagrams
Soft Systems Methodology, AGILE, Scrum, JIRA

Table-4: Requirements of CPMo for SCD (interview findings)

CPMo Requirements	Interviewees
Ability to model complex processes representing interdependencies between multiple processes, departments & stakeholders	1, 9, 10
Ability to represent interconnectivities among cross-sectoral sub-processes	9, 10
Allow multiple inputs from multiple stakeholders	1, 9, 10
Allow cross-sectoral stakeholder collaboration in process mapping	1, 9, 10
Allows to dynamically change inputs and outputs	3
Allows to link process maps directly to the project requirements	9
Addresses the data related challenges	1, 3, 4, 7, 8, 9
Addresses city's interoperability needs	1, 2, 3, 4, 5, 8, 9, 10, 11, 13
Addresses Security requirement	8
Visualisation of cross-sectoral process flows to resolve potential cross-sectoral legislation conflicts	1, 9, 10
Visualisation of End to end process maps to multiple stakeholders to allow decision making	1, 9, 10, 11, 12
KPI's visualisation and realisation	3, 5, 6, 7, 8, 10, 13
Visualisation of costs/benefit/action lines	10, 13
Visualisation of cross sectoral regulations	1
Visibility of impact on multiple stakeholder	9, 10
Visibility of impact on process flows due to departmental legislation	1
Visual representation of project milestones	3

Table-5: Challenges encountered during city process modelling (interview findings)

Challenges during CPMo
People related challenges (skills, change management, clarity of vision)
IT related challenges (varying levels of technical infrastructure in different sectors)
Information capture from organisational silos
Inefficient process captures due to organisational complexity
Non-standardisation of existing processes
Stakeholder collaboration needs
Data challenges with ownership, complexity, data compatibility, security, and privacy
City council challenges with legislation, bureaucracy and regulation

Table-6: CSFs for addressing possible challenges during CPMo (interview findings)

CPMo Requirements	Interviewees
Clarity of shared vision and goals for successful future state visualisation	1, 3, 4, 5, 6, 7, 8, 10, 12
Citizen participation in data gathering - required for data availability requirement for the smart city project	6, 7, 8, 10, 11, 12
Adequate IT infrastructure	6, 13
Stakeholder identification, communication, engagement commitment, and management (cross sectoral, multiple service providers)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
Selection of ideal tool for accurate process capture	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12
Cross sectoral project collaboration	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
Appropriate Information and Requirements gathering methodology	1, 5, 7, 8, 9, 10, 12
Availability of skilled workforce	2, 3, 8, 10, 11, 13
Identification of mandates of stakeholders and identification of how the mandates intersect each other	5