Comparative Analysis of Conceptual and Domain Models

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Abstract

Conceptual modelling is *the elicitation and the representation of the general knowledge that an Information System (IS) operating in a specific domain needs to know* (cf. (Antoni, 2007), (Rolland, 2007)). Describing a domain of the real world through conceptual models means viewing it in a particular way, i.e. through the assumption that the world consists of concepts, e.g. entities, objects, events, processes ((Johannesson, 2007), (Antoni, 2007)). In particular, conceptual modelling aims at representing static (e.g., objects, entities) and dynamic phenomena (e.g., events and processes) in a particular domain (Wand and Weber, 2002). Domain Modelling is a term related to Domain Engineering. Domain engineering is a process for developing a set of reusable assets (analysis and design models, software architectures and software components) for a family of IS operating in a particular domain. It differs from the traditional software engineering process as software engineering aims at developing models, architectures and components for a specific IS while domain engineering aims at a family of IS (Czarnecki and Eisenecker, 2000). In this work, we review the field of Policy Modelling models and delineate research gaps and opportunities following a Systematic Literature Review (SLR) method. SLR is an essential feature of any academic research as it creates a firm foundation for advancing knowledge, facilitating theory development, closing areas where a plethora of research exists, and uncovering areas where research is needed (Webster and Watson, 2002).

1. Introduction to Conceptual and Domain Modelling

Conceptual modelling (CM) is *the elicitation and the representation of the general knowledge that an IS operating in a specific domain needs to know* [9] [14]. Describing a domain of the real world through conceptual models means viewing it in a particular way, i.e. through the assumption that the world consists of concepts, e.g. entities, objects, events, processes [13] [9]. In particular, conceptual modelling aims at representing static (e.g., objects, entities) and dynamic phenomena (e.g., events and processes) in a particular domain [10].

CM is an essential part of IS development [11] [18] [19] [16] which traditionally consists of the analysis, design, and implementation stages (Figure 1). IS analysis transforms a perceived real-world domain (or universe of discourse [17]) into a conceptual model, while design and implementation transforms the model, into a design model and an IS eventually [11].

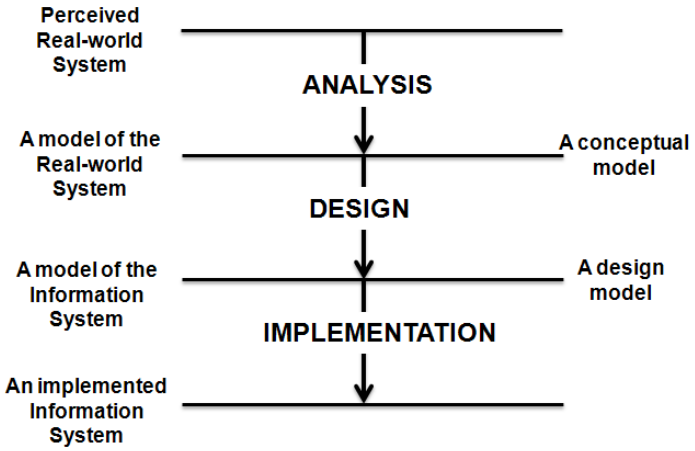

Figure 1 The role of a conceptual model in systems development (adapted from [11])

CM encompasses three four elements [10]:

- the CM grammar [11] (or CM notation [12]) that provides a set of constructs and rules showing how to combine the constructs in order to model the real world domain [10]. The IS literature includes a vast variety of conceptual modelling grammars including data-oriented, process-oriented and object-oriented ones, [9] [18] [17] [10] [20] [18] [22].
- the CM method (or modelling technique [20] [23]) that prescribes how to map the real phenomena of the domain into a model of the domain [10]. A rather limited number of CM methods exist in the literature [10] [18].
- the CM script (or conceptual schema [9] [18], [12], [19], [16] [14] or conceptual model [20], [22]) is the output of the CM method and is constructed using a CM grammar [10]. It is usually one (or more) diagrams [18] depicting the domain's concepts. A great variety of conceptual scripts have been proposed in the literature [10] [18] [23] [9].
- the CM context, which is the setting in which conceptual modelling occurs and scripts are used.

Domain Modelling is a term related to Domain Engineering (DE). DE is a process for developing a set of reusable assets (analysis and design models, software architectures and software components) for a family of IS operating in a particular domain. It differs from the traditional software engineering (SE) process as SE aims at developing models, architectures and components for a specific IS while DE aims at a family of IS, (Czarnecki & Eisenecker, 2000). The parallelism between DE and SE is clear in Figure 2.

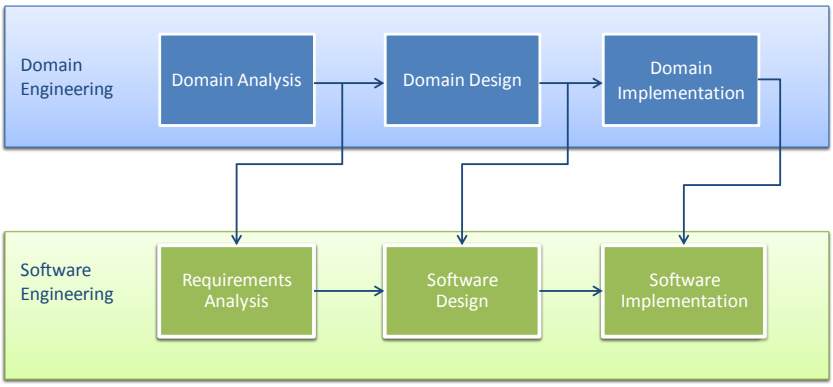

Figure 2 The parallelism between Domain Engineering and Software Engineering, adapted from **(Czarnecki & Eisenecker, 2000)**.

DE encompasses three main processes: (i) domain analysis (DA) referring to the gathering and the modelling of the domain knowledge, (ii) domain design concerning the establishment of a common architecture for the systems in the domain and (iii) domain implementation which is about implementing the software reusable assets, (Czarnecki & Eisenecker, 2000), (Harsu, 2002). The main output of DA is the domain model, i.e. an explicit representation of the most important and enduring concepts (or entities, objects), behaviour (or functions, events) and relationships describing a particular business domain, (Bennett, McRobb, & Farmer, 2010). The components of a domain model are not clear in the literature, (Arrango, 1994). A number of approaches propose different components included in the domain model, (Czarnecki & Eisenecker, 2000), (Kang, Cohen, Hess, Nowak, & Peter, 1990), (Tracz & Coglianese, 1992), (Champeaux, Lea, & Faure, 1993), (Prieto-Diaz, 1990), (Harsu, 2002), (Ferre & Vegas, 1999), (Bennett, McRobb, & Farmer, 2010). By reviewing these approaches, we infer that a domain model consists of the following components: (i) the domain definition, (ii) the conceptual models describing the concepts of the domain (i.e. entities, functions, events, relationships) and their taxonomy and (iii) the domain lexicon defining the domain vocabulary.

2. Methodology

In order to review the field of Policy Modelling (PM) models and delineate research gaps and opportunities we decide to follow a Systematic Literature Review (SLR) method. SLR is an essential feature of any academic research as it creates a firm foundation for advancing knowledge, facilitates theory development, closes areas where a plethora of research exists, and uncovers areas where research is needed [24]

We apply the Systematic Literature Review (SLR) method developed by Kitchenham [1]. The overall process followed is diagrammatically depicted in Figure 3 and is elaborated in the next paragraphs.

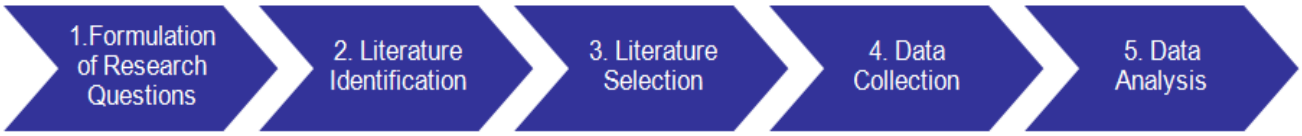

Figure 3 The methodology followed

2.1. Formulation of Research Questions

The research questions (RQs) addressed by this study are:

RQ.1 How much research activity on models for policy modelling has been done so far?
RQ.2 What types of models are proposed in the literature?
RQ.3 Which are the main modelling concepts?
RQ.4 What are the limitations /extensions of current research?

RQ1 concerns the identification of the nature of the existing literature and it can be further decomposed in the following RQs:

RQ1.1 How many articles concerning PM models have been published so far?
RQ1.2 In which time period have the articles been published?
RQ1.3 Which is the type (e.g. journals, conferences, workshops etc.) of the articles?
RQ1.4 Who leads the research on PM models?

RQ4 addresses the identification of research gaps and opportunities and it can be decomposed in the following:

RQ.4.1 Do the models include explicit guidelines for practical use?
RQ.4.2 Have the models been used in practice? In which policy domains? Are they transferable in other domains?
RQ.4.3 Which are the limitations of the models use?

2.2. Literature Identification

In order to identify literature relevant to the topic under investigation, we performed an automatic search process using well – known scientific libraries, i.e. Google scholar and ISI - Web of Knowledge. The terms used for searching were: policy modelling models, policy making models, policy formulation models, policy modelling domain, policy making domain, policy formulation domain, policy modelling AND models, policy making AND models and policy formulation AND models.

Additionally, as the topic is rather new and immature, we decided to also review ongoing R&D projects on policy modelling. For this purpose, we employed the portal of European Commission (*http://cordis.europa.eu/projects/home_en.html*) in order to identify such projects and search their publications.

Finally, we performed the "*go backward*" technique, i.e. we search for articles referenced to those selected for analysis.

2.3. Literature Selection

This step encompasses the literature selection according to relevance and quality criteria. The first activity undertaken is the relevance assessment of the literature. In particular, in our review we included articles about: domain, conceptual, data, process and meta-models for policy modelling, policy making and policy formulation. We excluded articles concerning models for e-

participation, opinion gathering, public policy argumentation and public consultation, as these topics are not fall into the domain under investigation; however they are relevant enough and therefore they were included in our search results. Then, we studied the titles, keywords, abstracts, and in some case the full text of the articles, in order to decide if they satisfy the inclusion criteria and not fall in the exclusion ones.

Next, we proceed to the quality assessment of the literature. In order to assure the quality of the results of tour review, we decided to include only scientific journal, conference, workshop and symposium articles subjected to the process of peer-review. Then, we examined the articles and selected only those conformed to the quality criteria.

2.4. Data collection

This step includes the determination of the coding scheme, i.e. the data to be extracted from each article, and the data extraction process. We developed the coding scheme based on the research questions posed in step 1 of our methodology. In particular, the data extracted from each article were:

- Title and full reference
- Year of publication
- The source (journal or conference) of each publication
- The author(s) and their institution
- The type of model (e.g. domain, conceptual etc)
- The modelling grammar and the modelling scripts used (if any)
- The modelling concepts
- Practitioner-based guidelines for the use of the model
- Examples of practical use (ref to projects / cases)
- Policy domain in which the model has been used
- Transferability in other policy domains
- Constraints of the model use

Then, we studied the articles and recorded the above data in table format. Following good practice [1], the data extraction process has been performed by two researchers, one recorded the data and the other checked the extraction process.

2.5. Data analysis

The data was tabulated to show:

- The number of models published per year, their source, authors and institutions (addressing RQ1)
- The number of studies per model type and modelling grammar (addressing RQ2)
- The modelling concepts used in the domain and their frequency of appearance (addressing RQ3)
- Whether the model proposes practitioner-oriented guidelines (addressing RQ4.1)

- Examples of practical use of each model and the policy domains in which the model has been used (addressing RQ4.2)
- The transferability of the model in other policy domains (addressing RQ4.2)
- The constraints of the use of the model (addressing RQ4.3)

3. Results – Discussion of Research Questions

In this section we discuss the answers to the research questions posed in this study.

3.1. RQ.1: How much research activity on models for policy modelling has been done so far?

This research question is decomposed in 4 sub-questions which are answered next.

3.1.1. RQ1.1 How many articles concerning PM models have been published so far?

We identify 5 scientific articles about PM models. Table (in Appendix 1) shows the results of the literature identification and selection process. In particular, we identified 5 articles highly relevant to the domain under investigation. For each article we recorded all the data referenced in section 2.4 - Data collection. The extracted data are presented in detail in Tables 1, 2 and 3.

3.1.2. RQ1.2 In which time period have the articles been published?

The identified articles have published from 2010 to 2013. Table 1 shows the number of publications per year. It is noted here that we did not identify any publication prior to 2010.

Year	Number of Publications
2010	1
2011	3
2012	0
2013	1

Table 1 Number of publications per year

The distribution of the publication over the years indicates that PM models is a rather immature research topic that requires further investigation.

3.1.3. RQ1.3 Which is the type (e.g. journals, conferences, workshops etc.) of the articles?

As far as the type of the articles concerned, one is published in a journal, one is presented in a Conference and the others are presented in a Workshop, the Workshop on Modelling Policy Making (MPM 2011) namely which was dedicated to the research topic under investigation. We examined all the articles presented in this Workshop, however only 3 of them were considered relevant according to the criteria defined in section 2.3 - Literature Selection. Table 2 indicates the number of articles per article type.

Type of Article	Number of Publications
Journal Article	1

Conference Article	1
Workshop Article	3

Table 2 Number of articles per article type

The above table indicates that only preliminary research results on PM models have been published so far.

3.1.4. RQ1.4 Who leads the research on PM models?

Taking into consideration the data included in, it is obvious that European researchers authored all the identified articles. Each of the 13 authors mentioned in the articles participated in only one publication. With the exception of [3] all other publications were authored by researchers belonging to the same institution.

The above facts indicate that Europe leads the research in PM models. It also points out that no collaborative articles, among institutions, has been published so far.

3.2. RQ.2: What types of models are proposed in the literature?

Table *8* clearly indicates that literature includes both structural and functional models. It is noted here that structural models represent the static phenomena, while functional models represent the dynamic phenomena of the domain. A mix model is a model that includes both structural and functional models. Table 3 displays the number of articles per model type.

Type of Model	Number of Publications
Structural Model	2
Functional Model	2
Mixed	1

Table 3 Number of articles per article type

As far as modelling grammar concerned, UML is the most prominent of them. In particular the grammars used per article are depicted in the next table.

Modelling Grammar	Number of Publications
UML	3
Ontology	1
Flowchart notation	1

Table 4 Number of articles per modelling grammar

The modelling scripts used are mostly UML diagrams and a flow chart. One paper [7] describes an ontology which is not presented in a modelling script format. Next table elaborates on the scripts used per publication.

Modelling Script	Number of Publications
UML class diagram	2
UML use case diagram	1

UML activity diagram	1
Flowchart	1

Table 5 Number of articles per modelling script

3.3. RQ.3: Which are the main modelling concepts?

For answering RQ3, we had to identify the domain structural and functional concepts, i.e. entities / objects and activities / processes. The identified concepts per publication are depicted in

Table ***8***.

In particular, we identified 58 unique concepts of structural models. The majority of structural concepts (59) appear in one model each. The concept *Stakeholder* of [4] appears as *Actor in* [7] and as Agent in [5] and the concept *Action* appears in two models [7] [5]. Additionally, we identified 27 unique concepts of functional models. All functional concepts appear only in one model each.

This heterogeneity in concepts stems from the fact that each model is specialized for the policy modelling processes defined in each project.

3.4. RQ.4: What are the limitations /extensions of current research?

The sub-questions composing RQ4 are addresses next. All data needed for answering the sub-questions are presented in
Table ***9***.

3.4.1. RQ.4.1 Do the models include explicit guidelines for practical use?

Only 2 out of 5 articles include explicit guidelines for practical use of the proposed model
This fact hinders the wide adoption of the proposed models. This fact probably stems from the immaturity of the field and the fact that most of the published model are preliminary and need to be elaborated more

3.4.2. RQ.4.2 Have the models been used in practice? In which policy domains? Are they transferable in other domains?

All the models have been used in R&D projects funded by European Commission (EC). Table 6 shows the number of models concern each project. Therefore, it may be concluded that EC is the major instigator of research on PM models.

R&D Project	Number of models
OCOPOMO	2
IMPACT	2
eGovPoliNet	1

Table 6 Number of models per R&D project

Only 2 models have been used in specific PM domains. One model [5] has been used in 3 domains (energy, financial and social policy domain), while one [6] has been used only in the energy policy domain. The other three models have not been used in any particular domain.
As far as transferability concerned, only one model [6] has developed for a specific policy domain (energy) and for a specific geographic region (Kosice, Slovakia). The other 4 models are not concerning any particular policy domain and therefore can be used in any policy field.

3.4.3. RQ.4.3 Which are the limitations of the models use?

A major limitation of the identified models is that they built using incomplete domain. In particular models construction is based upon knowledge gathered from real policy formulation cases of specific countries as well as by domain experts.
Furthermore, all models are specialized for the PM process defined in each project, e.g. OCOPOMO follows a PM process based on scenarios while IMPACT follows a collaborative PM process

4. Conclusions

In this work, we perform a SLR on conceptual and domain PM models. We identified 5 articles, 1 journal and 4 Conference/ Workshop articles, published through 2010-2013. The research on the domain is mainly stimulated by EC through funding R&D projects on PM. The research topic is rather immature and requires further investigation as only preliminary results have been published so far

The identified models cover both structural and functional aspects of PM. The most prominent modelling grammar is UML and the modelling scripts used include UML class, activity and use case diagrams and flow charts. The structural and functional concepts present great heterogeneity. In particular, we identified 58 unique structural and 27 functional concepts. This heterogeneity in concepts stems from the fact that each model is specialized for the policy modelling processes defined in each project

The limitations of current research on PM models is that the models (a) incorporate incomplete domain knowledge, (b) are specialized for the PM process defined in each project and (c) do not include guidelines for practical use of the model

A valuable extension of current research is the development of a generic domain model for PM that will be based on integrated domain knowledge, will be transferable to any policy domain and will include guidelines maximizing the its use.

5. References

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6. Appendix A: Data Extracted from each article

Article	Reference	Article Type	Source	Authors	Organisation	Year
[1]	Kaliva, E., Panopoulou, E., Tambouris, E., & Tarabanis, K. (2013). A domain model for online community building and collaboration in eGovernment and policy modelling. Transforming Government: People, Process and Policy, 7(1), 109-136.	Journal	Transforming Government: People, Process and Policy	Kaliva E. Panopoulou E. Tambouris E. Tarabanis K.	Centre for Research & Technology Hellas (CERTH)	2013
[2]	Scherer, S., & Wimmer, M. (2011). Conceptual Models Supporting Formal Policy Modelling: Metamodel and Approach. In proceedings of the JURIX 2011 Workshop on Modelling Policy Making (MPM 2011) , pp. 23-28	Workshop	JURIX 2011 Workshop on Modelling Policy Making (MPM 2011)	Wimmer M. Scherer S.	University of Koblenz-Landau	2011
[3]	Furdik, K., Sabol, T., & Dulinova, V. (2010). Policy modelling supported by e-participation ICT tools. In proceedings of the 4th international conference on methodologies, technologies and tools enabling e-government (MeTTeG'10) , pp. 135-146	Conference	4th international conference on methodologies, technologies and tools enabling e-government (MeTTeG'10)	Frudik K. Sabol T. Dulinova V.	Intersoft SA Technical University of Kosice Kosice Region	2010
[4]	Wyner, A., Atkinson, K., & Bench-Capon, T. (2011). Semantic Models and Ontologies for Modelling Policy-Making. In proceedings of the JURIX 2011 Workshop on Modelling Policy Making (MPM 2011) , pp. 17-22	Workshop	JURIX 2011 Workshop on Modelling Policy Making (MPM 2011)	Wyner A. Atkinson K. Bench-Capon T.	University of Liverpool	2011
[5]	Gordon, T. (2011). The Policy Modeling Tool of the IMPACT Argumentation Toolbox. In proceedings of the JURIX 2011 Workshop on Modelling Policy Making (MPM 2011) , pp. 29-38	Workshop	JURIX 2011 Workshop on Modelling Policy Making (MPM 2011)	Gordon T.	Fraunhofer FOKUS	2011

Table 7 Articles about PM models and authors details

Article	Model Type	Modelling Grammar	Modelling Scripts	Structural Modelling Concepts	Functional Modelling Concepts
[1]	Mixed	UML	UML - Class Diagram UML - Use Case Diagram	Researcher, Policy maker, Practitioner, Other interested Party, Guest, Interested Party, Expert, Project, Publication, Case, Scientific Article, Policy, Other Publication, Event, Discussion, File Sharing, One-to-one Communication, Joint Authoring, Scientific Areas, eGovernment, eParticipation, Policy Modelling, Academic Discipline, Political Science, Computer Science, Management Science, Research Practice, Future Vision, Grand Challenge, Comparative Analysis, State-of-play Analysis	Register, View Publicly Available Resources, Disseminate Activities to Social Media, Get Informed for Events, Search Knowledge Database, Introduce New Member, Establish Connections with Experts, Initiate Discussions, Join Collaboration Team, Collaborate on Thematic Fields, Comment on Knowledge Resources, Publish Collaboration Results, Set-up Collaboration Team, Manage Knowledge Resources, Manage Events
[2]	Structural	UML	UML - Class Diagram	Consistent Conceptual Description, Concept, Actor, Object, Attribute, Relation, Action, ActionInputOutput, Instance, RelationInstance, AttributeInstance	-
[3]	Functional	Flowchart Notation	Flowchart	-	Needs identification, Involve partners, Conduct research, Reviewers nomination, Review & comment, Evaluate comments, Release, Policy monitoring
[4]	Structural	Ontology	-	State, Current Circumstance, Concequence, Agent, Action, Joint Action, Goal, Value	-
[5]	Functional	UML	UML - Activity Diagram	-	Edit & publish policy model, Analyse effects of policies on cases

Table 8 Modelling Elements identified in each article

Article	Examples of practical use	Policy domain	Transferability	Guidelines	Constraints
[1]	eGovPoliNet project	N/D	Y	Y	Constantly evolving domain
					incompleteness of the domain knowledge gathered (by experts)
					specialized for the online community building and collaboration in eGov and PM
[2]	OCOPOMO project	Finance	Y	Y	incompleteness of the domain knowledge gathered (by real cases)
		Energy			specialized for the policy making process followed within the OCOPOMO project
		Social			
[3]	OCOPOMO project	Energy	N/D	N	incompleteness of the domain knowledge gathered (by Kosice region only)
					specialized process for the Kosice region
[4]	IMPACT project	N/D	Y	N	specialized for collaborative policy making
[5]	IMPACT project	N/D	Y	N	specialized for the IMPACT approach, i.e. online collaborative policy making

Table 9 Use and Limitations of each article