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Review

Review

Standardized languages and notations for graphical modelling of patient care processes: a systematic review

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Standardised languages and notations for graphical modelling of patient care processes: a systematic review

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ABSTRACT

Purpose: The importance of working toward quality improvement in healthcare implies an increasing interest in analysing, understanding and optimising process logic and sequences of activities embedded in healthcare processes. Their graphical representation promotes faster learning, higher retention, and better compliance. The study identifies standardised graphical languages and notations applied to patient care processes and investigates their usefulness in the healthcare setting.

Data Sources: Peer-reviewed literature up to 19/05/2016. Information complemented by a questionnaire sent to the authors of selected studies.

Study selection: Systematic review conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement.

Data extraction: Five authors extracted results of selected studies.

Results of data synthesis: Ten articles met the inclusion criteria. One notation and language for health care process modelling were identified with an application to patient care processes: *Business Process Model and Notation* and *Unified Modeling Language*™. One of the authors of every selected study completed the questionnaire. Users' comprehensibility and facilitation of inter-professional analysis of processes have been recognised, in the filled in questionnaires, as major strengths for process modelling in health care.

Conclusion: Both the notation and the language could increase the *clarity of presentation* thanks to their visual properties, the capacity of easily managing macro and micro scenarios, the possibility of clearly and precisely representing the process logic. Both could increase guidelines / pathways *applicability* by representing complex scenarios through charts and algorithms hence contributing to reduce unjustified practice variations which negatively impact on quality of care and patient safety.

Keywords: Process Assessment (Health Care) [MeSH]; Process modelling; Graphic representation.

PURPOSE

The importance of working toward quality improvement in healthcare implies an increasing interest in analysing, understanding and optimising healthcare processes.[1] These processes may involve a network of heterogeneous components, each one being an agent with freedom to act and adapting capabilities, and may be influenced by the emerging of self-organized behaviours. Such a complex nature may produce unpredictable overall results.[2-3] Healthcare processes can be classified into two macro categories: *patient care processes*, and *organizational* or *administrative processes*. Patient care processes are executed according to a diagnostic–therapeutic cycle, comprising observation, reasoning and action, directly linked to the patient. Organizational/administrative processes are patterns that support medical treatment via the co-ordination of different people and organizational units. Here we focus on patient care process within *Clinical Practice Guidelines* (CPGs) and *Clinical Pathways (CPWs)*.

CPGs have emerged as a source of support for health professionals, policymakers, and patients/public aspiring to make healthcare decisions on the basis of the best available evidence.[4] CPGs, as defined by the World Health Organization (WHO) and Institute of Medicine (IoM),[5-6] aim to improve quality of care, reduce unjustified practice variations and reduce healthcare costs.[7] However, issues exist that can prevent optimum implementation of CPGs. When analysing the characteristics of a CPG, the "complexity of the guideline" is the most frequently described factor influencing its implementation.[8] *Guideline developers* tend to focus on specific tasks rather than on time-extended processes such as in care plans.[9] When guideline recommendations are unclear, users may question their rigor and reliability. It is therefore essential that interpretability is addressed within the guideline development phase.[4] Schünemann et al.[10] reported that bridging the gap between clinical research and everyday healthcare practice requires finding ways to help guideline *developers* (health professionals, methodologists, epidemiologists, statisticians, and others) in making guidelines understandable and implementable by users (clinicians, patients, and others). These are key factors also in internationally recognised methodological documents for CPG development and appraisal.[11-14]

CPWs are a common component in the quest to improve the quality of health and there is a worldwide rising of their implementation and usage in healthcare.[15] CPWs, aimed to improve patient outcomes and organization efficiency through standardizing care practices, are focused on processes, and require a multidisciplinary participatory approach during design and implementation.[16-17] CPWs present several challenges also for their conceptualization and implementation.[17] Their multidisciplinary nature requires attention on the cohesiveness of the working team and a common plan to better understand hospital staff roles in the process of care for an effective development and implementation.[17-18]

Faster learning, higher retention, and better compliance can be obtained by graphically displaying decision logic (algorithms), sequences and timing of activities, especially when dealing with complex or unclear situations;[19] in such case, the adoption of multiple diagram types is recommended to manage the many inter-linked issues between task, people and information/material in a clearly understood way.[20] The adoption of algorithms is also recommended specifically for improving CPGs use.[21]

The aim of the present work was to identify standardised languages and notations for graphical modelling and representation adopted for *patient care processes* and to assess them in terms of the ease of understanding of notations and symbols, the clearness of the graphical representation and the benefits of their adoption in the healthcare setting. The choice of focusing only on standardised solutions came from our belief that the formalization of healthcare process should be based on a common understanding with precise and well-known semantics.

DATA SOURCES

A systematic review of literature was carried out and a questionnaire was submitted to one author of every selected study. This systematic review conforms to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[22]

Searches were conducted on 19 May 2016 in the following databases: Global Health, Ovid Healthstar, Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Ovid MEDLINE® Daily and Ovid MEDLINE®. The strategy combined the following terms: healthcare process, process of care, patient care process, patient care management, and visual, graphic, representation, notation, language, description, model, diagram, workflow (full search in Supplementary file 1). Only articles published since 2000 were considered.

Reference lists of relevant studies were screened and experts consulted to identify further studies satisfying the selection criteria. Web of Science (WoS) and the Google Scholar were also searched to identify additional relevant papers citing the selected studies.

STUDY SELECTION

Studies describing or assessing the use standardised languages and notations for graphic representation of any healthcare process, including applications in the development, representation, communication, dissemination or implementation of CPGs or CPWs, were considered. Only works in English, Italian or Spanish were included. Papers concerning mathematical and stochastic models were excluded. Applications outwith the healthcare setting or applied to purely organizational issues were also excluded.

After removal of duplicates, *Abstrackr*[23] was used to collaboratively screen citations for relevance (title and abstract).

Five reviewers, two for each paper, were involved in the study selection process. Disagreements were resolved by consensus. The same approach was adopted also for eligibility check on full texts.

One member of the team was responsible for identifying and removing duplicate references (RG).

DATA EXTRACTION

A data collection form was developed by the authors, pilot-tested on two studies and refined accordingly. Each review author independently filled in the data collection form for each selected study whose final content was agreed after internal discussion.

The questionnaire, intended to integrate and/or clarify the information retrieved through the papers, investigated formal evaluation activities and authors' opinions on the used modelling language/notation in terms of usefulness in the healthcare setting. Respondents were chosen according to the following criterion: for each selected paper, we invited the corresponding author or the last author to participate or to give an alternative author to contact that could be representative of the research group. With reference to the "personal evaluations" section, a five-point *Likert* scale was adopted. The full questionnaire, realised with the open source web based *LimeSurvey*®[24], is reported as Supplementary File 2.

RESULTS OF DATA SYNTHESIS

The results of the selection process are shown in Figure 1. From 1,777 potentially relevant reports initially identified after eliminating duplicates, 10 studies were selected.[25-34]. Two authors were contacted for additional information: Askari[29] to specify the composition of the panel of stakeholders interviewed for modelling the health care process; Scheuerlein[28] to provide additional information on the implementation phase referred to in his paper.

Characteristics and findings of included studies

The identified applications of graphical languages / notations, allow to understand who is using them, under which circumstances, and with which expected benefit (Table 1).

All but one paper[34] reported the intended users of the process representation: health professionals, as the primary target audience, administrative staff, managers, computer scientists and statisticians. Eight papers [25-29,31-32,34] investigated the representation of a CPW and two focused on a guideline[30,33] with different levels of details (health professionals, working units, organizations, systems of organizations) addressing several health issues. Graphical representation of health care processes has been used for five distinct purposes (expected benefits): to

- evaluate and improve the referred program;[25-26,29]
- enhance transparency and clearness of the referred processes;[27,31-32]
- develop a CPW based on an existing CPG;[28]
- facilitate the development of a computer system;[30] and
- capture, store and present details of patient flow through the processes of care.[33-34]

Working team and methodological approach used in the healthcare process analysis and modelling of selected studies are shown in Table 2.

In all the studies, the working teams involved in the modelling phase were composed by process knowledge holders (e.g., health professionals, administrative staff) and process analysts (e.g., experts in computer science, operational research, management science applied to health care, statisticians, knowledge engineers, and system modelling).

The modelling phase was conducted with different approaches, all referable to qualitative research methods (see details in Table 3).

Askari et al.[29] and Ferrante et al.[31] were the only studies reporting an evaluation/validation stage. Additional information was obtained through the survey (see next section).

Languages/notations adopted for the healthcare process modelling and covered process items are shown in Table 3.

All included studies used the same notation or language for health care process modelling: the *Business Process Model and Notation* (BPMN)[25-28] and the *Unified Modeling Language*™ (UML®)[29-34].

BPMN[35] is a standard notation and consists of one diagram, called the *Business Process Diagram*, which is based on a flowcharting technique tailored for creating graphical models of business process operations including the actors performing each task. BPMN allows modelling on several levels of details from macro to micro process representations. BPMN is supported by graphical object properties that enable the generation of the *Business Process Execution Language*, a standard executable language for specifying actions within business processes with web services.[36]

All the studies justified their use of BPMN: ability to graphically model processes and events with a good formalization level and to provide a standardised communication framework between multiple actors of any kind of role. BPMN ease of use by non-IT people was also accounted for [25,27-28] together with its diffusion and maturity in the clinical context[25-26]. Furthermore, Scheuerlein et al. complemented BPMN with *Tangible Business Process Modeling* (t.BPM) technique. *t.BPM* is presented as a modular construction system of the BPMN symbols which enables the creation of an outline or raw model (i.e., by placing the symbols on a spread-out paper sheet).[28]

UML®[37] is a graphical language that offers a standard way for visualizing, specifying, constructing, and documenting a system's blueprint, including business process logic and system functions.[38] UML® has several diagrams which can be grouped into three categories representing static application structure, general types of behaviour, and different aspects of interaction.

In the six papers referring to UML®, four behavioural diagrams were adopted. All the papers included the *Activity diagram*, which is an enhanced form of flowcharts showing how different workflows in the system are constructed (also in this case, from macro representations to micro details), how they start and the potential decision paths that can be taken from start to finish, including the actors performing each task.[38] Ferrante at al.[31] and Vasilakis et al.[34] also included the *State Machine Diagram*, which details the transitions or changes of state an object can go through in the system and the rules that govern that change[38]. Choi at al.,[30] Ferrante et al.[31] and Vasilakis et al.,[34] in representing health care process, considered the *Use Case diagram* which is adopted to describe the proposed functionality of a system in terms of interaction between a user and the system[38]. Martin et al.[32] adopted also the *Timing diagrams* and *Sequence diagram* which are respectively used to focus on conditions changing within and among lifelines, and to display interactions between users and entities through a sequential map of messages over time.[38] Similarly to BPMN, the capacity of UML® to model business processes and Information and Communications technologies (ICT) systems can be exploited in order to support the execution of the modelled processes. The reason for having used UML® was also reported by authors. All the authors recognized UML® ability to graphically model processes and events using an international standard. Some authors also highlight the precise semantic of UML®, its being ease of use for non-IT people and wide use as a software writing tool.[29-32] Finally, Choi et al. and Vasilakis et al. also reported its beneficial effects of visualizing, specifying, constructing, and documenting the artefacts of a system from the end-users' perspective.[30,34]

The diagrams most commonly adopted within the included studies are the *Business Process Diagram* and *Activity Diagram*. As reported in Table 3, these allow to capture the key features of processes: a predetermined (sequencing) or conditional (gatewaying) ordering of work activities (what to do) executed by an actor (holder), with a beginning or triggering events (events), an end, and defined inputs and outputs in order to accomplish an organizational goal. This allows to clearly represent the complexity of healthcare processes and to support their comprehension by all the stakeholders.

Results from the questionnaire

The majority of the authors reported to have performed formal or informal evaluating activities related to *the language referred in the paper*. Four responders (Rojo, Askari, Martin, Taylor) reported evaluation activities on the *Ease of understanding of notations and symbols,* three (Rojo, Askari, Taylor) on the *Clearness of the realised graphical representation* and five (Overby, Rojo, Askari, Martin, Taylor) on the *Usefulness / benefits of employing the used graphical language for mapping the health care processes*. Results of the evaluation phases were reported only by few respondents: Rojo noted that, having examined the realised graphical representations, each user was able to clearly understand his/her own role. Askari confirmed the results already reported in her paper: a) the modeller concluded that the UML® activity diagram is able to easily capture the process activities as expressed by the stakeholders while; b) stakeholders were able to offer additional suggestions for process improvements; c) the external validator, blinded to the interviews and the modelling phase, was not able to answer all the queries on disease management based on the process model output. Martin reported that time duration and intervals for activities comprising patient journey through Emergency Department were understood without symbol tables or explanatory notes.

The second part of the questionnaire was focused on obtaining the authors personal evaluation of the used language/notation (Table 4).

No substantial difference emerges between the two languages. Users' comprehensibility and facilitation of inter-professional analysis of processes were recognised as strength points for both. Flexibility and usefulness were positively considered by all the responders. In two cases (Scheuerlein, Vasilakis) the tools were not judged fully intuitive for the users and, in three cases (Overby, Scheuerlein, Vasilakis), the benefits of employing BPMN or UML® for mapping the health care processes were considered moderately or scarcely counterbalanced by the amount of resources involved in the modelling activity. Four authors (Scheuerlein, Askari, Martin, Vasilakis) expressed some concern that the use of modelling languages may allow for early detection and correction of errors in the process.

DISCUSSION

Our work analysed papers on patient care process modelling and representation through graphical languages/notations. UML® and BPMN were identified.

All the authors adopted qualitative research methods in their works. This choice appears appropriate as qualitative research methods involve the systematic collection, organisation, and interpretation of material derived from talk or observation and are used in the exploration of meanings of social phenomena as experienced by individuals themselves, in their natural context.[39] In the field of health services research, qualitative methods have been used to describe many kinds of complex settings and complex interactions: among patients, families, and clinicians; within, between, and among professional groups and organizations; in communities; and in markets.[40] Moreover, it should be considered that programs are rarely implemented exactly as planned and qualitative methods have been invaluable in such cases.[40]

UML® and BPMN have the potential to contribute to increase the *clarity of presentation* through the promotion of standardised diagrams with:

- visual properties;
- capacity to manage macro and micro scenarios (i.e., nested representations and sub-processes can help especially with CPGs / CPWs with broad scopes);
- clearly and precisely representing process logic with details of target population, roles, recommended intervention and alternatives.

From the survey, users' comprehensibility and facilitation of inter-professional analysis of processes clearly outstand as positive characteristics of both UML® and BPMN. Due to their not fully intuitive profile, it is necessary to train non-technical users.

The availability of charts, algorithms, and decision aiding tools in CPGs / CPWs documentation has a recognised value for their *applicability*.[11-14] This aspect was among the main reasons for which BPMN and UML® were chosen. The ability of BPMN and UML® to capture complex process scenarios (see Table 4) can stimulate the production of charts and algorithms to be included in CPG /CPWs documentation. In order to increase CPG / CPWs *applicability*, the development of *Clinical Decision Support Systems* (CDSS) is recommended.[11-14] Both UML® and BPMN have native capacity of being adopted for developing ICT systems and can, consequently, be used also for integrating patient care processes into CDSS.

As recognised by the *Agree Next Steps* Consortium,[13] *evaluating* the application of guideline recommendations can facilitate their on-going *use*. This requires process and behavioural measures in addition to clinical or health outcome measures. UML® and BPMN provide an opportunity to discuss and visualise the logic within a process. This could support process evaluation actions by allowing activities, roles and resource requirements to be clearly modelled.[41] The recognised capacity of BPMN / UML® to support inter-professional working and the easy understanding of realised models allow to adopt the tools for promoting multidisciplinary participation and process evaluation.

We are aware that the overly positive picture resulting from our analysis could also rely on a possible publication bias due to the fact that negative experiences are rarely published. Further limitations in our work are the restricted selection of articles to those written in English, Spanish and Italian, and the absence of a statistical analysis of the questionnaires due to the small number of included studies.

CONCLUSION

We identified BPMN and UML® as standard languages / notations for graphical modelling and representation of patient care processes. According to the opinion of the authors of the selected studies, BPMN and UML® are understandable and useful for the users (health professionals, administrative staff, managers, computer scientists and statisticians), and allow inter-professional analysis of health care processes and representation of complex scenarios. Current evidence does not demonstrate any advantage in choosing the language rather than the notation, or vice versa. Their capacity to formalise processes in a standardised manner allows to increase process comprehensibility hence reducing unjustified practice variations which negatively impact on quality of care and patient safety. In order to further reduce possible misinterpretations, in our opinion graphical representation of healthcare processes should be adopted since the definition phase - with process knowledge holders strictly collaborating with analysts - and not as an ex-post translation.

While BPMN and UML® are widely adopted in other contexts, mainly when dealing with the development of Information Systems, our work shows a limited experience in patient care processes modelling.

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TABLES

Table 1 – Summary of Findings: context of the representation

Source (Country)	**Target Users**	**Represented subject**	**Expected benefit**
Barbagallo S et al. 2015,[25] (Italy)	Computer scientist, clinical staff (surgeons, anaesthetists, nurses, management) and management.	CPW adopted in an operating room (no specific health problem addressed).	To evaluate and improve the existing program.
Cutting EM et al. 2015,[26] (USA)	Clinicians.	CPW to adopt "CYP2C19 genotype test results for antiplatelet therapy to cardiac stent patients".	To evaluate and improve the existing program.
Rojo MG et al. 2008,[27] (Spain)	Health Professionals.	CPW for multiple purposes (Anatomic Pathology processes within programmed surgery).	To make the existing processes transparent and understandable.
Scheuerlein H et al. 2012,[28] (Germany)	Staff from operating room, ward and stoma nurses, anaesthesia, Intensive Care Unit psycho-oncology, social	CPW for Colorectal carcinoma treatment based on a national Guideline.	To develop a clinical pathway based on a Guideline.

Source (Country)	Target Users	Represented subject	Expected benefit
	services, medical and administrative staff.		
Askari M et al. 2013,[29] (The Netherlands)	Nurses specialized in falls, primary care physicians, geriatricians, primary care physicians and other clinicians, home care employees and managers.	CPW: local Program for Falls prevention (Home, primary care, specialised care).	To evaluate and improve the existing program.
Choi J et al. 2014,[30] (USA)	Genetic Nurses.	Lashley's genetic counseling guideline "Clinical Genetics in Nursing Practice"	To facilitate the development of a computer system.
Ferrante S et al. 2013,[31] (Italy)	Health professional (not detailed).	CPW (Stroke rehabilitation) based on international guidelines.	To enhance transparency and clearness of the referred processes.
Martin M et al. 2011,[32] (Australia)	ED staff, Healthcare staff, Computer Scientists, Statisticians.	CPW: local model of the patient journey through the Emergency Department (ED).	To enhance transparency and clearness of the referred processes.

Source (Country)	Target Users	Represented subject	Expected benefit
Sutton DR et al. 2006,[33] (UK)	Medical practitioners and pharmacists.	CPG for management of hypertension of the British Hypertension Society - Prevention at patient's pharmacies.	To capture, store and present details of patient flow through the processes of care.
Vasilakis C et al. 2009,[34] (UK)	Not Reported	CPW for diagnosis of fractured neck of femur for older people.	To capture, store and present details of the patients flow through the existing processes of care.

Table 2 – Summary of Findings: working teams and methodological approaches

Source	Working Team	Methodological approach / tools-steps
Barbagallo S et al. 2015[25]	*Process knowledge holders:* hospital's physicians (the surgeons and the anaesthetists). *Process analysts*: researchers with backgrounds in IT and management.	Optimization model The results of the application of the model to real clinical data are given and compared retrospectively to the current practice.
Cutting EM et al. 2015[26]	*Process knowledge holders:* clinicians from cardiology and endocrinology, laboratory professional, clinical research coordinators, cardiology fellows and nurse practitioners. *Process analysts:* Not reported.	Case Study Three two-hour focus groups, audio recorded, transcribed and coded using a qualitative research analysis platform.
Rojo MG et al. 2008[27]	*Process knowledge holders*: health professionals and administrative staff. *Process analysts*: Software engineers.	Action Research Six Phases (informative meetings, intensive training, process selection, definition of the work method, process describing by hospital experts, and process modelling)

Source	Working Team	Methodological approach / tools-steps
Scheuerlein H et al. 2012[28]	*Process knowledge holders*: 1 surgeon as clinical project director, 1 resident and 2 doctoral students. *Process analysts*: 1 external consultant-moderator as IT project director.	Pilot Project Interviews with stakeholders. Interviews conducted as personal conversation, in a mainly uniform fashion. All modelled processes subject to review to reach a consensus within the working team.
Askari M et al. 2013[29]	*Process knowledge holders*: 2 physicians. *Process analysts*: 4 medical informaticians.	Case Study Semi-structured interviews with stakeholders. Models reviews by stakeholders. Validation phase with: a) interviews (modeller); b) invitational symposium with 75 attendees and a panel of 9 experts, the stakeholders and other relevant interested parties; c) assessment (External validator)
Choi J et al. 2014[30]	*Process knowledge holders:* 1 experienced nurse and 2 experienced nurse informaticians. *Process analysts:* Not reported.	Case Study 1 experienced nurse involved in the revision of the activity diagram. 2 experienced nurse informaticians involved in the test of ease of use and usefulness of the UML®.
Ferrante S et al. 2013[31]	*Process knowledge holders:* multidisciplinary rehabilitation team of an advanced stroke-oriented rehabilitation centre	Case Study Interviews with representative people involved in the process (2 medical

Source	Working Team	Methodological approach / tools-steps
	Process analysts: Model developers.	doctors, 2 physical therapists, 1 language therapist, and 2 nurses) Validation phase involving both the analysts (model developers) and the experts of the domain (rehabilitation team).
Martin M et al. 2011[31]	*Process knowledge holders*: ED staff *Process analysts*: Healthcare staff, Computer Scientists, Statisticians	Mixed methods research design. An all-day workshop with Emergency Department (ED) staff. A continuous 4 days mapping exercise during which research assistants (recruited from the cohort of Monash medical students) independently observed and manually recorded patient journeys through the ED. A focus group with the research assistants regarding their observations of patient flow. The analysis of data obtained during the previous steps to construct dynamic models of the process.
Sutton DR et al. 2006[33]	*Process knowledge holders*: Clinician and clinical pharmacist. *Process analysts*: knowledge engineers	Case Study as a part of a research trial exploring the role community pharmacists could play in the management of hypertension. Six community pharmacies participating. 250 patients invited to participate.

Source	Working Team	Methodological approach / tools-steps
Vasilakis C et al. 2009[34]	*Process knowledge holders*: 1 Physician. *Process analysts*: 1 Expert in operational research / management, science applied to health care, and systems modelling and simulation; 1 Expert in Computer science.	Soft System Methodology. Semi-structured interviews; on-site meetings, direct observation of clinical rounds and multi-disciplinary team meetings; narrative.

Table 3 – Summary of Findings: used modelling languages/notations, covered process items and target users

Source	Modelling language/notation	Covered process items
Barbagallo S et al. 2015[25]	BPMN	Start, end, sub-processes, tasks, gateways (decisions/evaluations), sequence flows.
Cutting EM et al. 2015[26]	BPMN	Start, end, tasks, gateways, sequence flows. All items partitioned by specific actors.
Rojo MG et al. 2008[27]	BPMN	Start, end, sub-processes, tasks, gateways (decisions/evaluations), sequence flows, parallel branches, events, actors, data objects, message flows.
Scheuerlein H et al. 2012[28]	BPMN	Start, end, sub-processes, tasks, gateways (logic operators, decisions), sequence flows, parallel branches, events, data objects, message flows. All items partitioned by specific actors.
Askari M et al. 2013[29]	UML® (Activity diagram)	Start, end, tasks, gateways (decisions/evaluations), sequence flows, parallel branches, roles, bottlenecks (as notes), messages.
Choi J et al. 2014[30]	UML® (Activity and Use Case diagrams)	Start, end, tasks, sequence flows, parallel branches (Activity Diagram) Actors, Tasks (Use case diagram).
Ferrante S et al. 2013[31]	UML® (Use Case, Activity, and State Machine diagrams)	Start, end, tasks, Event Tasks, gateways (decisions/evaluations), sequence flows. All items partitioned by specific actors (Activity Diagram).

Source	Modelling language/notation	Covered process items
		Actors, start, end, tasks (Use Case diagrams). Initial/End states, States, Transitions (State Machine diagram).
Martin M et al. 2011[31]	UML® (Activity, Timing and Sequence diagrams)	Start, end, tasks, gateways (decisions/evaluations), sequence flows, parallel branches, interruptions [FlowFinal Node] (Activity diagram). States, State or condition timelines, Messages, Lifelines, Duration constraints, Time constraints, Events (Timing diagram). Messages, Lifelines, Duration constraints, Execution specifications, Interactions (Sequence diagram).
Sutton DR et al. 2006[33]	UML® (Activity diagram)	Start, end, tasks, gateways (decisions/evaluations), sequence flows.
Vasilakis C et al. 2009[34]	UML® (Activity, Use Case[1] and State Machine diagrams)	Start, end, tasks, gateways (decisions/evaluations), sequence flows (Activity diagram). Initial/End states, States, Transitions (State Machine diagram).

[1] *Use case diagram reported only in textual form*

Table 4 – Personal evaluations of the referred modelling language/notation (survey result)

Contacted author/ Study ref.	Referred modelling language / notation	It is intuitive for the users	After an appropriate training, it is understandable for the users	It allows inter-professional analysis of health care processes	It is enough flexible to represent complex scenarios	It allows early detection and correction of errors in the process	It is considered useful for the indented users	The overall benefits are worth the amount of involved resources
Barbagallo S[25]	BPMN	+	+	=	=	+	+	+
Overby CS[26]	BPMN	+	+ +	+ +	+	+	+	=
Rojo MG[27]	BPMN	+	+ +	+ +	+ +	+ +	+ +	+ +
Scheuerlein H[28]	BPMN	-	+	+	+	-	+	- -
Askari M[29]	UML®	+	+	+ +	=	=	+	+
Choi J[30]	UML®	+ +	+ +	+ +	+ +	+ +	+ +	+ +
Ferrante S[31]	UML®	+	+	+	+	+	=	+
Martin M[31]	UML®	+ +	+ +	+ +	+ +	=	+ +	+ +
Taylor P[33]	UML®	+	+	+	+	+	+	+
Vasilakis C[34]	UML®	=	+	+	+ +	-	+	=

[a] *Not considering the ones already accustomed with the language/notation*

Legend:

+ + means “strongly agree”

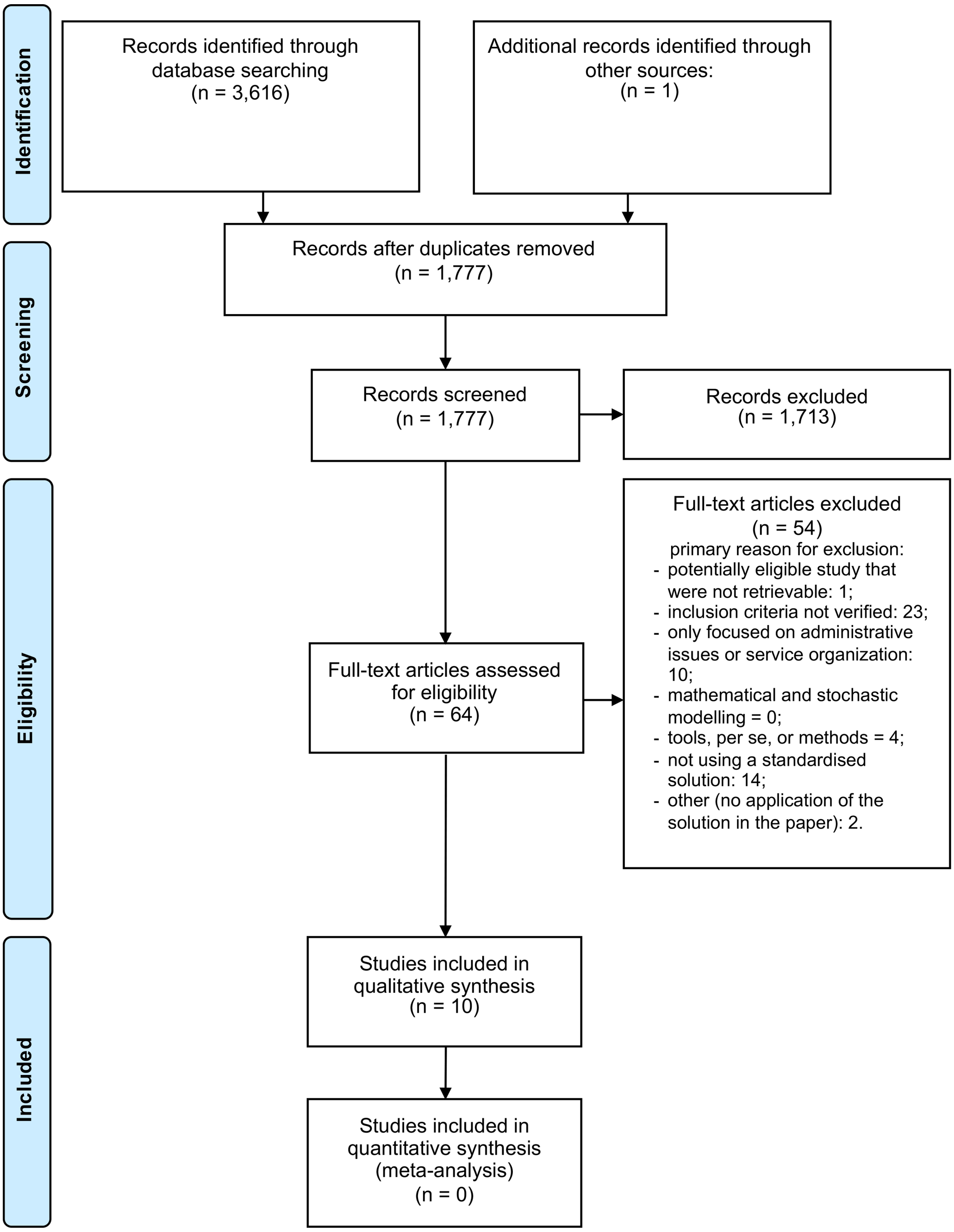
+ means “agree”

= means “neither agree nor agree”

- means “disagree”

- - means “strongly disagree”

Figure 1: PRISMA Flow Diagram



Supplementary file 1

Questionnaire related to the systematic review on languages and notations for graphically modelling of patient care processes.

The proposed questionnaire is part of a literature systematic review aimed at identifying languages and notations for graphically modelling and representing of patient care processes. The article

{TOKEN:ATTRIBUTE_1}

is one of the selected works.

The questionnaire has been thought to complement the information reported in the paper with respect to the objectives of our work.

Dear Prof. {TOKEN:LASTNAME},

Thank you for having accepted to answer the previously anticipated questionnaire.

Should you have any doubt do not hesitate to contact us (leo@ifc.cnr.it).

Warmest regards,

Maria del Mar Trujillo-Martín (Fundación Canaria de Investigación y Salud)
Carlo Giacomo Leo, Saverio Sabina, Giuseppe Ponzini, Pierpaolo Mincarone (Italian National Research Council)

There are 20 questions in this survey

Formal or informal evaluating activities.

[]
Have you performed formal or informal evaluating activities related to the language referred in the paper (UML/BPMN):

*****

Please choose **only one** of the following:

- ○ Yes
- ○ No

[]Report whether the evaluation deals with: *

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '1 [A]' (Have you performed formal or informal evaluating activities related to the language referred in the paper (UML/BPMN):)

Please choose **only one** of the following:

- ○ the model definition phase
- ○ the model reading/using phase
- ○ both

[]

Report if the focus of the evaluation deals with easiness of understanding of *notations* and *symbols*

*****

Only answer this question if the following conditions are met:
((A.NAOK == "Y"))

Please choose **only one** of the following:

- Yes
- No

[]Describe *methods* and *results* of the evaluating activity *

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '3 [A2i]' (Report if the focus of the evaluation deals with easiness of understanding of notations and symbols)

Please write your answer here:

[]

Report if the focus of the evaluation deals with *clearness* of the realised graphical representation

*****

Only answer this question if the following conditions are met:
((A.NAOK == "Y"))

Please choose **only one** of the following:

- Yes
- No

[ ]Describe *methods* and *results* of the evaluating activity *

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '5 [A2ii]' (Report if the focus of the evaluation deals with clearness of the realised graphical representation)

Please write your answer here:

[ ]

Report if the focus of the evaluation deals with *usefulness / benefits* of employing the used graphical language for mapping the health care processes

*****

Only answer this question if the following conditions are met:
((A.NAOK == "Y"))

Please choose **only one** of the following:

- Yes
- No

[]Describe *methods* and *results* of the evaluating activity

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '7 [A2iii]' (Report if the focus of the evaluation deals with usefulness / benefits of employing the used graphical language for mapping the health care processes)

Please write your answer here:

[]Report if ther focus of the evaluation deals with *other issues* and describe *methods* and *results*:

Only answer this question if the following conditions are met:
((A.NAOK == "Y"))

Please write your answer here:

Personal evaluations of the used notation/language

[ ]
Based on the reported research experience, how do you evaluate the following sentence: the referred language is intuitive for the indented users (not considering the ones already accustomed with the language)

*****

Please choose **only one** of the following:

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

[ ]Based on the reported research experience, how do you evaluate the following sentence: after an appropriate training, the referred language results understandable for the intended users (not considering the ones already accustomed with the language) *

Please choose **only one** of the following:

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

[ ]
Based on the reported research experience, how do you evaluate the following sentence: the referred language allows inter-professional analysis of health care processes
*****

Please choose **only one** of the following:

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

[]Based on the reported research experience, how do you evaluate the following sentence: the referred language is enough flexible to represent complex scenarios *

Please choose **only one** of the following:

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

[]Based on the reported research experience, how do you evaluate the following sentence: the referred language is considered useful for the indented users *

Please choose **only one** of the following:

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

[]Based on the reported research experience, how do you evaluate the following sentence: the referred modelling language allows early detection and correction of errors in the process *

Please choose **only one** of the following:

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

[]Based on the reported research experience, how do you evaluate the following sentence: the overall benefits of employing the used graphical language for mapping the health care processes are worth the amount of involved resources (personnel involved, time, other costs, etc. *

Please choose **only one** of the following:

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

Specific question

[ ]In the modelling of the health care process you obtained data based on interviews to stakeholders. Could you please specify how it is composed the panel of stakeholders referred in the paper? *

Only answer this question if the following conditions are met:
Your Email address is <m.askari@[…]>

Please write your answer here:

[ ]

In the methodology the following sentence is reported:

"[…] This is followed by a test and possibly simulation and optimization. After proper checks the organizational implementation follows as a last step".

Could you please provide additional information on the implementation phase?

*****

Only answer this question if the following conditions are met:
Your Email address is <hubert.scheuerlein@[…]>

Please write your answer here: