

Field Guide to Shareable Clinical Pathways

BPM+ (BPMN, CMMN & DMN) in Healthcare

Version: 2.0

OMG Healthcare Domain Taskforce

healthcare@omg.org

This paper presents a discussion of technology issues considered in a Subgroup of the Object Management Group. The contents of this paper are presented to foster wider discussion on this topic; the content of this paper is not an adopted standard of any kind. This paper does not represent the official position of the Object Management Group.

Revision History

	Date	Version
Draft Review	2/1/2019	.1
Review	4/19/2019	.2
Review for Comment	8/20/2019	.3
Draft Update	10/1/2019	.4
Final Review	11/4/2019	.5
Release	12/10/2019	Version 2.0

LICENSES

The companies listed above have granted to the Object Management Group, Inc. (OMG) a nonexclusive, royalty-free, paid up, worldwide license to copy and distribute this document and to modify this document and distribute copies of the modified version. Each of the copyright holders listed above has agreed that no person shall be deemed to have infringed the copyright in the included material of any such copyright holder by reason of having used the specification set forth herein or having conformed any computer software to the specification.

Subject to all of the terms and conditions below, the owners of the copyright in this specification hereby grant you a fully-paid up, non-exclusive, nontransferable, perpetual, worldwide license (without the right to sublicense), to use this specification to create and distribute software and special purpose specifications that are based upon this specification, and to use, copy, and distribute this specification as provided under the Copyright Act; provided that: (1) both the copyright notice identified above and this permission notice appear on any copies of this specification; (2) the use of the specifications is for informational purposes and will not be copied or posted on any network computer or broadcast in any media and will not be otherwise resold or transferred for commercial purposes; and (3) no modifications are made to this specification. This limited permission automatically terminates without notice if you breach any of these terms or conditions. Upon termination, you will destroy immediately any copies of the specifications in your possession or control.

PATENTS

The attention of adopters is directed to the possibility that compliance with or adoption of OMG specifications may require use of an invention covered by patent rights. OMG shall not be responsible for identifying patents for which a license may be required by any OMG specification, or for conducting legal inquiries into the legal validity or scope of those patents that are brought to its attention. OMG specifications are prospective and advisory only. Prospective users are responsible for protecting themselves against liability for infringement of patents.

GENERAL USE RESTRICTIONS

Any unauthorized use of this specification may violate copyright laws, trademark laws, and communications regulations and statutes. This document contains information which is protected by copyright. All Rights Reserved. No part of this work covered by copyright herein may be reproduced or used in any form or by any means--graphic, electronic, or mechanical, including photocopying, recording, taping, or information storage and retrieval systems--without permission of the copyright owner.

DISCLAIMER OF WARRANTY

WHILE THIS PUBLICATION IS BELIEVED TO BE ACCURATE, IT IS PROVIDED "AS IS" AND MAY CONTAIN ERRORS OR MISPRINTS. THE OBJECT MANAGEMENT GROUP AND THE COMPANIES LISTED ABOVE MAKE NO WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, WITH REGARD TO THIS PUBLICATION, INCLUDING BUT NOT LIMITED TO ANY WARRANTY OF TITLE OR OWNERSHIP, IMPLIED WARRANTY OF MERCHANTABILITY OR WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE OR USE. IN NO EVENT SHALL THE OBJECT MANAGEMENT GROUP OR ANY OF THE COMPANIES LISTED ABOVE BE LIABLE FOR ERRORS CONTAINED HEREIN OR FOR DIRECT, INDIRECT, INCIDENTAL, SPECIAL, CONSEQUENTIAL, RELIANCE OR COVER DAMAGES, INCLUDING LOSS OF PROFITS, REVENUE, DATA OR USE, INCURRED BY ANY USER OR ANY THIRD PARTY IN CONNECTION WITH THE FURNISHING, PERFORMANCE, OR USE OF THIS MATERIAL, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

The entire risk as to the quality and performance of software developed using this specification is borne by you. This disclaimer of warranty constitutes an essential part of the license granted to you to use this specification.

RESTRICTED RIGHTS LEGEND

Use, duplication or disclosure by the U.S. Government is subject to the restrictions set forth in subparagraph (c) (1) (ii) of The Rights in Technical Data and Computer Software Clause at DFARS 252.227-7013 or in subparagraph (c)(1) and (2) of the Commercial Computer Software - Restricted Rights clauses at 48 C.F.R. 52.227-19 or as specified in 48 C.F.R. 227-7202-2 of the DoD F.A.R. Supplement and its successors, or as specified in 48 C.F.R. 12.212 of the Federal Acquisition Regulations and its successors, as applicable. The specification copyright owners are as indicated above and may be contacted through the Object Management Group, 140 Kendrick Street, Needham, MA 02494, U.S.A.

TRADEMARKS

MDA®, Model Driven Architecture®, UML®, UML Cube logo®, OMG Logo®, CORBA® and XMI® are registered trademarks of the Object Management Group, Inc., and Object Management Group™, OMG™, Unified Modeling Language™, Model Driven Architecture Logo™, Model Driven Architecture Diagram™, CORBA logos™, XMI Logo™, CWM™, CWM Logo™, IOP™, IMM™, MOF™, Business Process Modeling Notation (BPMN), Case Management Modeling Notation (CMMN), Decision Modeling Notation (DMN), MDMI, OMG Interface Definition Language (IDL)™, and OMG SysML™ are trademarks of the Object Management Group. All other products or company names mentioned are used for identification purposes only and may be trademarks of their respective owners.

COMPLIANCE

The copyright holders listed above acknowledge that the Object Management Group (acting itself or through its software to use certification marks, trademarks or other special designations to indicate compliance with these materials.

Software developed under the terms of this license may claim compliance or conformance with this specification if and only if the software compliance is of a nature fully matching the applicable compliance points as stated in the specification. Software developed only partially matching the applicable compliance points may claim only that the software was based on this specification but may not claim compliance or conformance with this specification. In the event that testing suites are implemented or approved by Object Management Group, Inc., software developed using this specification may claim compliance or conformance with the specification only if the software satisfactorily completes the testing suites.

Acknowledgements

Name	Organization
John Butler	Auxilium Technology Group
Keith Butler	University of Washington
Denis Gagne	Trisotech
Steve Hasley	American College of Obstetricians and Gynecologists
Peter Haug	Intermountain Health / University of Utah
Robert Lario	University of Utah / US Department of Veterans Affairs
Ken Lord	US Department of Veterans Affairs
Sean Muir	US Department of Veterans Affairs
Ken Rubin	US Department of Veterans Affairs
Jane Shellum	Mayo Clinic
Davide Sottara	Mayo Clinic
Christine Watts	Consultant
Steve White	US Department of Veterans Affairs

Copyright © 2020, Object Management Group, Inc.

Executive Summary

Need

Healthcare throughout the world is growing in expense and complexity. As new technologies and medications are developed, and new care options become available, the ability for the healthcare community to provide quality care is improving and yet the risks of complications and miscommunications are greater without a better understanding of data and workflow requirements in a multi-provider healthcare environment. The great potential for health information technology (HIT) to improve the efficiency and quality of clinical health care has yet to be fully realized on a consistent, industry-wide basis. Despite major increases in the power and flexibility of computing there remains a gap between our ability to implement technology and our ability to understand how that technology will impact the performance of care. Synchrony between information flow and the appropriate workflow of clinical care is a key principle for usability, efficiency, and care quality. When HIT design decisions are not based on improving the efficiency and quality of clinical health care, the resulting solution can rearrange clinical workflow by accident rather than by design. This Guide aims to make an explicit, understandable connection between HIT and the methodical improvement of clinical health care.

Approach

This *Field Guide to Shareable Clinical Pathways* focuses on a model-based approach to define the workflow of care and decision-making at the level of granularity that reveals information needs. The approach of this Field Guide is to apply standard techniques for business process modeling and for decision modeling that are proven for other industries and apply them to the distinct aspects of the workflow of care and decision-making.

The Business Process Model and Notation (BPMN) standard is our choice for workflows. BPMN is a formal graphical and computable language that was developed to diagram processes that are performed by teams of people who must coordinate their activity while using computing to support both information work and physical activities that use and change information. A key goal is to foster community building among all types of stakeholders. The use of a well-defined standard to create workflow diagrams promotes a common understanding of their meaning by different participants. The Case Management Model and Notation (CMMN) complements BPMN with additional capabilities for unstructured behaviors triggered and continuously influenced by the information flowing into the case.

Similarly, the Decision Model and Notation (DMN) standard was chosen because it provides an understandable table format to model the combinations of factors that must be considered for complex, clinical decisions. Our experience indicates the visual diagrams of BPMN and with the decision tables of DMN can be learned quickly by clinical personnel with minimal training to critique them for accuracy and appropriateness, thus allowing them to participate in decisions about HIT impact. This Field Guide provides examples in which clinical personnel played key roles in workflow and decision modeling with these standards.

Conclusion

There are many reasons to develop a clear understanding of clinical care and decision making. In the most general terms, if we do not have a model-based understanding of how care is performed currently, then we cannot analyze and design cost effective improvements. Without cost-effective improvements, we cannot address the US and international critical need to improve efficiency, control the growth of health care expense, or continue to improve quality. This Field Guide is offered as a practical step towards realizing the great potential of HIT's role for accessible, efficient, and high-quality health care.

Table of Contents

Contents

Executive Summary	6
Need 6	
Approach	6
Conclusion	6
Table of Contents	7
Table of Figures	11
1. Scope	13
1.1. Content	13
1.2. Motivation	13
1.3. Goal.....	13
1.4. Audience	13
1.5. Defining what Success Looks Like.....	14
2. Introduction.....	15
2.1. What is a Shareable Clinical Pathway?	16
3. Reading Models.....	18
3.1. Differentiating process (BPMN) vs case (CMMN)	18
3.2. Business Process Modeling Notation (BPMN) for Hello Patient	19
3.2.1. Events (Start, Intermediate and End)	19
3.2.2. Tasks and Activities.....	20
3.2.3. Lanes and Pools	21
3.2.4. Gateways	21
3.2.5. Data Object.....	22
3.2.6. Connectors – Sequence, Message Flows and Associations.....	22
3.3. Case Management Modeling Notation (CMMN) for Hello Patient	23
3.3.1. Case Plan Model	24
3.3.2. Tasks	25
3.3.3. Milestone.....	25
3.3.4. Entry and Exit Criterion.....	26
3.3.5. Case file (item).....	26
3.4. Hello world Doctor Visit Decision Modeling Notation (DMN).....	26

3.4.1. Decision	27
3.4.2. Business Knowledge Model.....	27
3.4.3. Knowledge Source	27
3.4.4. Information Requirement.....	27
3.4.5. Authority Requirement.....	27
3.4.6. Annotation.....	28
3.4.7. Hit Policy.....	28
3.4.8. Inputs Data	28
3.4.9. Output.....	29
3.4.10. Condition	29
3.4.11. Row	29
4. Producing Models.....	29
4.1. Qualities of Shareable Clinical Pathways.....	29
4.1.1. Project High Level Best Practices.....	31
4.1.2. Methodology for Clinical Pathway Modeling	31
4.2. High-Level Modeling Best Practices	32
4.3. Shareable Clinical Pathway Models.....	33
4.3.1. Clinical Pathway Library/5WH Model.....	33
4.3.2. BPMN Process Models.....	58
4.3.3. CMMN Case Models	65
4.3.4. DMN Decision Models.....	69
4.4. Relationships Between Clinical Pathway Models.....	73
4.4.1. Choosing between BPMN and CMMN.....	73
4.4.2. Use a Case (CMMN) at the Top of the Model Hierarchy	74
4.4.3. Connection between BPMN and DMN.....	75
4.4.4. Connection between CMMN and DMN.....	79
5. Consuming Models.....	81
5.1. Introduction.....	81
5.2. Discovery Phase.....	81
5.3. Assessment Phase	81
5.3.1. Applicability	81
5.3.2. Simulation.....	81
5.3.3. Acceptance	81

5.3.4. Localization Phase	82
5.4. Information, Semantics, and Terminologies	82
5.5. Implementation Phase	82
5.5.1. Automated vs. Manual Utilization.....	82
5.5.2. Standards-Based Technologies.....	84
6. Appendix A – The Information Ecology of Clinical Care	90
7. Appendix B – Design Patterns	92
7.1. DMN: Simple Scoring Algorithm.....	92
7.1.1. Description.....	92
7.1.2. Problem	92
7.1.3. Applicability	93
7.1.4. Pattern	94
7.1.5. Specific Example	94
7.2. DMN: Quantify – Interpret – Recommend (QIR).....	96
7.2.1. Description.....	96
7.2.2. Problem	96
7.2.3. Applicability	96
7.2.4. Pattern	97
7.2.5. Specific Example	99
7.3. BPMN / DMN: Decision / Action.....	101
7.3.1. Description.....	101
7.3.2. Problem	101
7.3.3. Applicability	101
7.3.4. Pattern	101
7.3.5. Specific Example	102
7.4. BPMN / DMN: Workflow-Interleaved Decisions Description.....	103
7.4.1. Problem	103
7.4.2. Applicability	103
7.4.3. Specific Example	103
7.5. DMN: Team-based decision	105
7.5.1. Description.....	105
7.5.2. Problem	105
7.5.3. Applicability	105

7.5.4. Pattern	105
7.5.5. Specific Example	107
7.6. DMN: Computer-aided decision support (CDS).....	107
7.6.1. Description.....	107
7.6.2. Problem	107
7.6.3. Applicability	107
7.6.4. Pattern	108
7.6.5. Specific Example	109
7.7. DMN: Multi-perspective (Treatment) Decision.....	109
7.7.1. Description.....	109
7.7.2. Problem	109
7.7.3. Applicability	110
7.7.4. Pattern	110
7.7.5. Specific Example	111
7.8. DMN: Team-based decision	111
7.8.1. Description.....	111
7.8.2. Problem	112
7.8.3. Applicability	112
7.8.4. Specific Example	112
8. Appendix C – Sustainment and Governance.....	114
8.1. Governance Goals.....	114
8.2. Content Management	115
8.3. Asset Management.....	116
8.4. Choosing an Ecosystem	116
9. Appendix D – Glossary of Terms	118
10. Appendix E – Hello Patient Models.....	120
11. Suggested Readings.....	124
12. Future Work	125

Table of Figures

Figure 1 – The Balance between BPMN	18
Figure 2– BPMN Outweighs CMMN	19
Figure 3 – BPMN Events	20
Figure 4 – BPMN Tasks is a Rule or Decision Task.....	21
Figure 5 – Pools, Gateway and End Events	23
Figure 6 – CMMN Outweighs BPMN	23
Figure 7 – BPMN Perform Examination.....	24
Figure 8 – CMMN Tasks	25
Figure 9 – When to Use DMN	26
Figure 10 – Decision Requirement Diagram (DRD)	28
Figure 11— Decision Table	29
Figure 12 – Examples of Library/5WH Model Activities.....	37
Figure 13 – RACI	42
Figure 14 – Input, Outputs & Both.....	47
Figure 15 – When / Event	48
Figure 16 – Trigger & Results	49
<i>Figure 17 – Decision Artifacts</i>	<i>51</i>
Figure 18 – Decision Output Data Object.....	52
Figure 19 – Knowledge Model Diagram for the "Hello Patient" Example – with Legend	56
Figure 20 – Using Activities.....	59
Figure 21- Placeholder Sub-Process	61
Figure 23 – Input and Output Data Objects	68
Figure 24 – DMN, BPMN and CMMN Shared Clinical Pathways.....	73
Figure 25 – Mapping Between a BPMN Business Rule Task and a DMN Decision	75
Figure 26 – Mapping Between a BPMN Data Object and a DMN Decision (Output)	76
Figure 27 – Mapping Between a BPMN Data Object and a DMN Input.....	77
Figure 28 – Relationship Between a BPMN Business Rule Task and an Exclusive Gateway	77
Figure 29 – Business Rule Task Output as Source of Data for Exclusive Gateway Expressions.....	78
Figure 30 – An Example of an Exclusive Gateway Sequence Flow Expression.....	79
Figure 31 – Mapping Between a CMMN Decision Task and a DMN Decision	79
Figure 32 – Mapping Between a CMMN Case File Item and a DMN Input.....	80
Figure 33 – An Example of an Entry Criterion If Part Expression	80
Figure 34 – A Performance Dependency in CMMN	85
Figure 35 – A Performance Dependency in BPMN.....	85
Figure 36 – CMMN Case Model of a Patient Examination.....	86
Figure 37 – BPMN Sub-Process Converted from CMMN Model of Patient Examination	87
Figure 38 – The same Patient Examination Process modeled with a BPMN Ad Hoc Subprocess	88
Figure 39 – Patient with Suspected PE	93
Figure 40 – the simplest form of the DRD for this pattern	94
Figure 41 – Table Representation of PE Decision	94
Figure 42 – Revised Geneva Score DRD	95
Figure 43 – Revised Geneva Score Decision Table.....	95
Figure 44 – Generic Decision Requirements Diagram illustrating the quantify/interpret pattern	97
Figure 45 – Interpretation of Score Decision Table	97
Figure 46 – Recommendation decision based on a quantitative sub-decision.....	98
Figure 47 – Generic Decision Table	98

Figure 48— Quantify Interpret Recommend	98
Figure 49 – Interpretation / Recommendation decision table	99
Figure 50 – Quantify – Interpret: BMI	99
Figure 51 – Quantify – Recommend – CHADS2VAsc.....	100
Figure 52 – Quantify – Interpret – Recommend: Pulmonary Embolism / Diagnostic Testing.....	100
Figure 53 – BPMN diagram with exclusive gateway	101
Figure 54 – Pulmonary Embolism Workup Decision.....	102
Figure 55 – Interleaved BPMN & Decision.....	103
Figure 56 – Interleaved DRD.....	104
Figure 57 – DMN – Team-based decision pattern	105
Figure 58 – Team-based decision Generic Example	106
Figure 59 – Team-based decision specific example	107
Figure 60 – DMN: Computer-aided decision support (CDS)	108
Figure 61 – DMN: Computer-aided decision support (CDS) Specific	109
<i>Figure 62 – Multi-perspective (Treatment) Decision Pattern</i>	<i>110</i>
Figure 63 – Multi-perspective (Treatment) Decision Pattern.....	111
<i>Figure 64 – DMN: Team-based BPMN decision</i>	<i>113</i>
Figure 65 – DMN: Team-based CMMN decision	113
Figure 66 – Asset Metadata Set.....	116
Figure 67 – Hello Patient BPMN Main Process.....	120
Figure 68 – Hello Patient BPMN Take Vital Signs Process	120
Figure 69 – Hello Patient CMMN Main Case.....	121
Figure 70 – Hello Patient CMMN Examine Patient Case	122
Figure 71 – Hello Patient DMN Decision Services	123

1. Scope

1.1. Content

This field guide focuses on Shareable Clinical Pathways. Clinical Pathways are sometimes referred to as Clinical Guidelines, Clinical Workflows, Integrated Care Pathways, Multidisciplinary Pathways of Care and some other variances. When used herein, Clinical Pathways means “structured, multidisciplinary plans of care designed to support the implementation of clinical guidelines and protocols. Clinical pathways have four main components: a timeline, the categories of care or activities and their interventions, intermediate and long-term outcome criteria, and the variance record (to allow deviations to be documented and analyzed)¹.

To make Clinical Pathways shareable it is recommended to use internationally accepted standards where possible. In particular, this Field Guide provides guidance on using Business Process Model and Notation (BPMN), Case Management Model and Notation (CMMN), and Decision Model and Notation (DMN). These models have definable entry points, exit points, goals, and roles, are organized around a specific clinical topic, and are intended to be shareable across organizations. The models allow for localization while maintaining the essence of the clinical pathway. Examples used in the field guide were developed by a work group who used BPMN, CMMN, and DMN to create an example clinical pathway for antenatal care. These examples highlight the use of these notations with applicable constraints, extensions, and intersections with other formalisms.

1.2. Motivation

The use of these three modeling notations, particularly BPMN, is well established in business. However, the healthcare environment presents unique challenges which prompted the creation of this Field Guide. Perhaps more so than in other domains, health information technology systems are defined in terms of human tasks, both manual and cognitive, as well as computational tasks. The information resides in multiple locations, including not only the computer systems, but in paper documents, white boards, equipment, the observable environment, and the patient. Information exchange and transformation are complex, and a piece of information may be the object of work in one subprocess, and a resource in another. Workflows and information flows run in parallel and intersect at multiple points in multiple ways.

1.3. Goal

The *Field Guide to Shareable Clinical Pathways* is applicable to processes occurring in the course of providing care, including clinical, administrative, and revenue cycle processes, with an emphasis on the clinical processes. The goal of the Field Guide is to enable modeling of multi-team processes within organizations and sharing processes between organizations.

1.4. Audience

This Field Guide is targeted at healthcare professional staff with responsibility for capturing, documenting, vetting, and deploying processes and workflows within an organization. The expectation is that these staff either

¹ <http://www.openclinical.org/clinicalpathways.html>

will have (or will be trained for) a working understanding of the modeling formalisms that are used within this document.

The remainder of the document is divided into three sections that focus on the role they have within the organization in relation to clinical pathways. The three Field Guide audience roles are these:

- Readers should be familiar enough with the three modeling standards (BPMN, CMMN, and DMN) so that they can view and understand the basic behaviors defined in those models (see “Reading Models,” below). Readers are not expected to understand all the technical model definitions necessary for model execution; nor are they expected develop Shareable Clinical Pathways.
 - ❖ *Note that it is not expected that front-line healthcare providers will be reading the Shareable Clinical Pathway models. However, those healthcare professionals that are responsible for ensuring that clinical pathways are properly performed within their organization should be able to read and understand Shareable Clinical Pathways.*
- Producers should be well-versed in the three modeling standards (BPMN, CMMN, and DMN) to the extent that they can follow this Field Guide to create consistent and valid Shareable Clinical Pathways (see “Producing Models,” below).
- Consumers should be well-versed in the three modeling standards (BPMN, CMMN, and DMN) and the technologies available to the organization that will enable implementation of the Shareable Clinical Pathways. Consumers will “localize” the Shareable Clinical Pathways to fit within their organization’s technical capabilities (see “Consuming Models,” below).

1.5. Defining what Success Looks Like

Simply put, this document is intended to be handed to a member of a “modeling team”, and when that individual follows the guidance here, the resultant work product would be “shareable” (e.g. portable) with other institutions. In other words, the systematic application of the method and style described within this Field Guide should ensure portability of the work products within or between institutions, namely “Shareable Clinical Pathways”.

As a result, the specific content of this guide will provide actionable, testable, implementable criteria to influence how models are conceived, created, documented, and expressed. Stylistic guidance will provide clear direction to allow for consistency and repeatability across process flows and institutions of care. Compliance criteria will be objective and evidence-based, allowing for objective evaluation.

2. Introduction

Providing consistently high-quality healthcare is difficult. The demands on healthcare providers and complexity of the healthcare system seem to be increasing exponentially. Medical knowledge is expanding so rapidly that it is almost impossible to keep up without the support of health information technology. Providing healthcare is a complex process, involving multidisciplinary teams with multiple handoffs across care settings. Increasingly, systems supporting coordinated care teams are demonstrating the ability to achieve better outcomes. However, the complexity of healthcare makes building such systems costly to design, build, and maintain ... and extremely challenging to share among organizations. The entire healthcare community could benefit if the designs for these complex systems could be developed in way that they could be shared between organizations and tailored to fit within a particular environment.

Fortunately, the healthcare community has a unique asset it can leverage to address these challenges: the proven ability of the community to collaborate and share data, information, and knowledge. Collaboration is built into the DNA of medicine and medical research. Likewise, the healthcare technology community – including standards organizations (e.g., SNOMED and Health Level-7) and professional organizations (e.g., the American Medical Informatics Association, Health Information and Management Systems Society, and American Health Information Management Association) – have a culture of collaboration and innovation as well as a commitment to reducing the technical barriers to delivering high-quality healthcare. In particular, numerous health information technology groups have attempted to create "computer interpretable guidelines" aimed at leveraging technology to support clinical workflows. These groups developed various healthcare-specific modeling languages and approaches, but none has been widely adopted and applied.

The Business Process Management in Health Workgroup (BPMHW) of the Object Management Group (OMG) was formed to demonstrate the suitability of existing OMG modeling standards for publishing, sharing, and applying models and specification documents that describe clinical pathways with a goal of accelerating the development of health information technology solutions. The workgroup brings together participants with experience in healthcare standards and technical standards. The OMG is well-suited for this work; like healthcare technology organizations, the OMG as a community has collaboration in its DNA. The OMG has more than 20 years of experience in defining standards for developing and documenting complex systems with shareable, re-usable, and extensible models and design documents.

The OMG's current standard languages – including Business Process Model and Notation (BPMN), Case Management Model and Notation (CMMN), and Decision Model and Notation (DMN) – provide a solid foundation of formal semantics to model complex systems across business domains. There already exists a large international community of commercial and open-source tools that support these standards.

The BPMHW has created the Field Guide to Shareable Clinical Pathways as a handbook to help business analysts and knowledge engineers create models; clinical experts understand and validate models; and programmers and systems analysts implement the models. The Field Guide will leverage the work and lessons learned of the BPMHW Pilot Group who are modeling actual, implementable clinical pathways based on identified healthcare use cases. As time permits and the community grows, this approach will lead to a growing library of shareable clinical process documents.

- The core principles of the BPMHW are:
- Address workflow modeling of healthcare systems with a focus on clinical pathways.
- Leverage and use current standards, both healthcare specific and general technical standard, whenever possible.

- Incorporate existing systems into the new innovative solutions. A "greenfield" approach is not appropriate given the urgency of these solutions and the existing human and capital investment in existing systems.
- Process design documents must be actionable.
- Process design documents must be shareable, re-usable, customizable, and extensible.

2.1. What is a Shareable Clinical Pathway?

A clinical pathway defines the activities, data, and goals of a specific topic of care for a patient (e.g., Oncology, Antenatal Care). In general, a clinical pathway is the information and actions that provide for the enactment of a patient's Care Plan (<https://www.hl7.org/fhir/careplan.html>). Well-documented clinical pathways can improve communication by providing consistent and coordinated workflow steps and goals to patients and care-team members to ensure common practices and results. Further, the clinical pathways will help define the data requirements necessary for interoperability among systems and healthcare organizations. It is with this coordination that clinical pathways aim to improve the coordination and outcomes of care over time.

Clinical pathways can be in the form of narrative text, which is understandable for healthcare professionals and business analysts but is open to large variations of interpretation. To make them useful as the basis for implementing healthcare workflows or decision-support systems they must be made explicit with formal, repeatable semantics. Some recent efforts (e.g., Health Level Seven Knowledge Artifacts and FHIR Plan Definitions) use formal programming languages to define the workflow of Clinical Pathways. These programming languages provide the tools necessary for developers to implement healthcare workflows or decision-support systems. However, they are not readily understandable by healthcare professionals and business analysts. Furthermore, both text narratives and programming languages are difficult to maintain over time, since there is no clear way to pinpoint where changes should be made to the definitions due to changes in the environment or technology.

To improve the capabilities and usability of clinical pathway definitions, the BPMHW has developed a new approach. Using the Guide to Shareable Clinical Pathways, which describes a lightweight methodology for utilizing three OMG standards, business analysts – rather than IT staff – can develop Shareable Clinical Pathways. The three standards are the Business Process Model and Notation (BPMN), the Case Management Model and Notation (CMMN), and the Decision Model and Notation (DMN) specifications. Collectively, the three standards (BPMN, CMMN, and DMN) will be referred to as "BPM+." A Shareable Clinical Pathways should be designed in a way that if Care Plans derived from the application of a pathway to a given patient are successfully executed, then that patient's care (delivery) experience will comply with clinical guidelines.

Through the graphical notations provided by the BPM+ standards, which are backed by execution semantics, Shareable Clinical Pathways provide technological rigor yet are understandable by business analysts and healthcare professionals. A single Shareable Clinical Pathway may be comprised of combination of BPM+ models. These are linked together to provide a detailed Knowledge Model describing the work, data, and decision requirements of a clinical pathway. Thus, a Shareable Clinical Pathway is a type of Knowledge Model and we will use the term Knowledge Model throughout the Field Guide.

Shareable Clinical Pathways are of value to healthcare organizations in the following ways:

- They follow a model-driven approach: Shareable Clinical Pathways are Platform Independent Models (PIMs).
 - They identify the work and data requirements of a clinical pathway but do not define a specific platform for its implementation.

- Consumers of a Shareable Clinical Pathway will create a Platform-Specific Model (PSM) that localizes the workflow to the technology available to that consumer.
- Thus, they are shareable:
 - Shareable Clinical Pathways can be produced by one organization and that pathway can be utilized and localized by another organization or across multiple sites within the same organization.
 - The localization of a Shareable Clinical Pathway will satisfy the defined work and data requirements. That is, the execution of the Shareable Clinical Pathway will provide consistent results in spite of different implementation details.
- The models of a Shareable Clinical Pathway can be understood by business analysts, healthcare professionals, and IT developers.
 - The behavioral requirements of a Shareable Clinical Pathway can be directly validated by the healthcare professionals responsible for their implementation instead of "throwing them over the wall" to IT developers, trusting that the programming language code will meet those requirements.
- Shareable Clinical Pathways are based on domain-independent BPM standards.
 - The BPM standards are semantically rich enough to provide the behavioral capabilities required to define workflows for the healthcare domain.
 - The BPM+ standards are supported by a wide range of modeling and execution tools (e.g., there are 80-plus tools that support BPMN).
 - There are multiple sources of documentation and training for the standards, including university courses.
 - Thus, there is an increasing pool of trained modelers for the standards that can be used instead of training staff to learn a new, healthcare-specific programming language.
- The BPM Healthcare Field Guide provides the basis for Shareable Clinical Pathways to be developed in a consistent manner across multiple organizations.

3. Reading Models

The purpose of this section is to provide the *Reader* with a quick overview of the major elements within the three modeling perspectives (BPMN, CMMN, and DMN): process modeling, case modeling, and decision modeling. The section will also provide the reader with depictions of a simple Shareable Clinical Pathway example called "Hello Patient" and explanations of the highlighted element(s). References for further reading of the modeling languages will be provided.

The "Hello Patient" example used within this section is based on a doctor visit. The models shown are meant to be accurate and representative of a doctor visit, but they are for illustration purposes only; as such, they are not necessarily complete or generalizable. This section is not meant to be a tutorial but, rather, a contextual overview of key elements.

3.1. Differentiating process (BPMN) vs case (CMMN)

Shareable Clinical Pathways can be captured using a combination of both process (BPMN) and case (CMMN). It is therefore useful to understand the difference between them. A *Producer* of a Shareable Clinical Pathway must determine which of the two model languages is appropriate for a particular set of activities. Many Shared Clinical Pathways will use both types of models to accurately define the workflow of the pathway.

When a portion of a clinical pathway's preferred sequence is known and fairly deterministic (i.e., structured work), it can be documented and modeled using BPMN. However, when a portion of the pathway is more "event-driven" (i.e., unstructured work), such as with doctor examinations, CMMN may provide a more appropriate set of modeling elements and associated notation. The [Figure 1](#) below illustrates the balance between the two modeling languages.



Figure 1 – The Balance between BPMN

In actuality, there is no hard line to force the decision between the two languages. There are many sets of activities that can be modeled with either one. It will be up to the *Producer* to choose the best fit. The table below lists other general characteristics of BPMN and CMMN languages that will help the *Producer* make a choice.

BPMN Characteristics	CMMN Characteristics
Imperative	Declarative
Activity centric	Data centric
Deterministic Sequence	Non-Deterministic Sequence
Guided Work	Enabled Work

Table 1 – The General Characteristics of BPMN and CMMN models

- ❖ Note that DMN decision models can be useful in conjunction with both BPMN or CMMN models as a way to specify complex decision logic. The sections below will illustrate the characteristics of each type of model.

3.2. Business Process Modeling Notation (BPMN) for Hello Patient

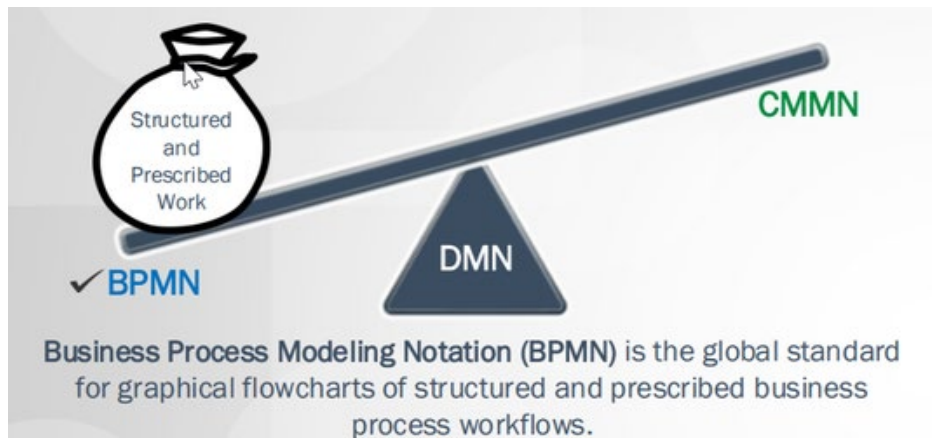


Figure 2– BPMN Outweighs CMMN

What follows are snippets of the example model that can be found in Appendix E, Hello Patient BPMN. The reader will be directed to sections of the OMG BPMN Specification version 2.0.2 (<http://www.omg.org/spec/BPMN/2.0.2/PDF>) for further elaboration. There are resources that may be better suited as an introduction to BPMN; this section is provided only to ensure that the reader is nominally familiar with BPMN.

3.2.1. Events (Start, Intermediate and End)

Events are things that occur during the life of a process. An event can start a process, end a process, or happen during a process.

Shown in the [Figure 3](#) below ("BPMN Events") below, *Timer Start Event* marks the beginning of a process. There are seven different types of start events for identifying when and under what circumstance a process can be instantiated. Here, the time event initiates the start of the process when a specific allotment of time has expired. For a description of the other types of start events the reader should see page 238 of [BPMN OMG Specification](#) for detailed descriptions.

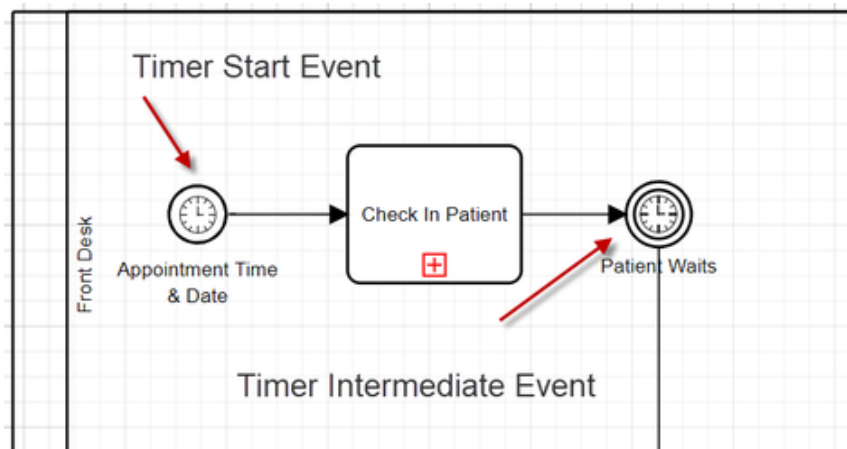


Figure 3 – BPMN Events

The *Timer Intermediate Event* occurs within a process as seen above in [Figure 3](#). There are two concepts to note here:

1. The first is the *notation* of an intermediate event; an event occurring mid-process during an actively executing process. Intermediate events occur while a process is under way. That is different than causing a process to begin execution as seen with *Start Events* or ending a process as seen with *End Events*. Intermediate events have two thin outer circles whereas start events have one thin outer circle and end events have one thick outer circle.
2. Second, the *type* of intermediate event depicted here is a "Timer" event. Here the intermediate Timer event will cause the process to pause for a specified period of time. Other Intermediate events await a specific action or condition to occur before execution commences. The reader should see page 249 of the [BPMN OMG specification](#) for further explication of Intermediate Events.

End events mark the completion of a sequence of activities. The end may be just for a branch of larger flow or terminate the entire workflow. End events are identified by a dark outlined circle; a terminating end event contains a dark dot in the center (an example is shown in [Figure 5 Pools, Gateway and End Events](#), below). Note page 259 of the [BPMN OMG specification](#) for a table of different types of events and their corresponding explanation.

3.2.2. Tasks and Activities

Tasks and Activities depict the notion of work performed in a process (note page 385 of the [BPMN OMG specification](#)). Activities in BPMN can be one of the nine task types defined in the spec, a sub-process, or a called activity (used to link to another process).

The sub-process is shown with a small box containing cross hairs, representing the collapse of a more detailed activity definition. If tool-supported, clicking on the cross hairs will open the detailed activities represented by the collapsed sub-process icon.

Shown in [Figure 4](#) ("BPMN Tasks Is a Rule or Decision Task") is *Decide Treatment Plan*. This is an activity where information is assessed, and a disposition is determined.

- ❖ Note this Task is distinguishable from a Gateway (See [Figure 4](#) again) in that a Gateway is a diamond-shaped element that controls the flow of the process based upon the Gateway type (more on this below).

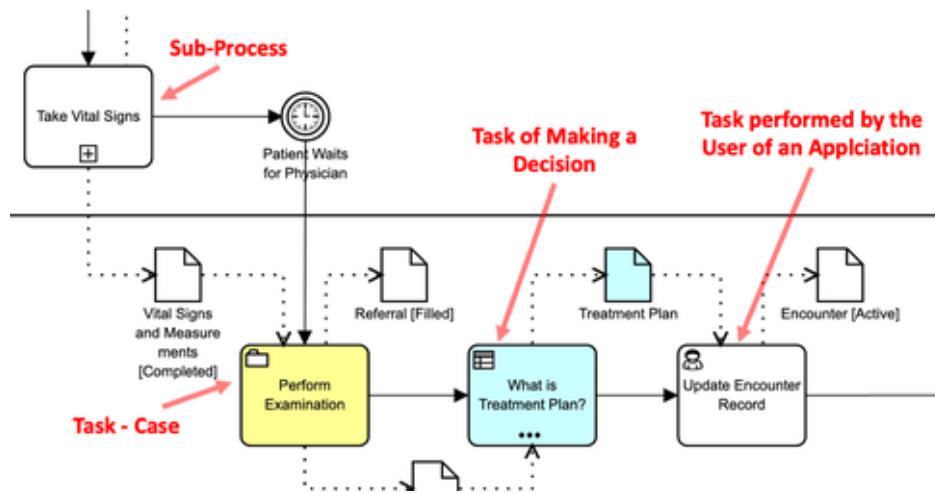


Figure 4 – BPMN Tasks is a Rule or Decision Task

3.2.3. Lanes and Pools

Lanes and *Pools* provide a mechanism for organizing activities. *Lanes* (sometimes called swim lanes) provide a visual container to organize activities within a Pool and are often associated with a business role, such as technician or primary-care provider (see page 304 of the [BPMN OMG specification](#)). They can be shown horizontally or vertically. Multiple Lanes can be used to show a sub-partitioning within a Pool (described below). Lanes are only informational for the reader and play no role in the execution of the process.

Pools (see page 111 of the [BPMN OMG specification](#)) also provide a means of organizing activities but contain an entire process. They show a complete body of work with a start and end; they are realized within a single process. When shown together within the same diagram, Pools represent the participants within a larger business collaboration. A Pool can represent an organization executing one flow, while another Pool may represent another organization's clinical workflow with messages communicating among the pools sharing data and maintaining synchronicity.

A Pool might also represent a doctor's office, sending messages to another Pool representing the lab performing tests. As stated above, a Pool may contain multiple lanes to help visually organize the activities depicting the roles or groups responsible for segments of the flow. It should be noted that sequence flows cannot cross Pool boundaries. Instead, Message Flows (See [Figure 5](#) Pools, Gateway and End Events, below) are used to capture interactions among pools.

3.2.4. Gateways

Gateways (see page 31 of [BPMN Specification](#)) are the point within a process where a flow may either diverge or converge. They represent control logic – but not decision logic – within the sequence of activities. This is an important distinction. The task of making a clinical assessment occurs within an activity, with the flow of the clinical pathway affected by this decision. For example, determining if a patient has diabetes or a high glucose level occurs within an activity in the flow preceding a gateway. For example, the gateway controls the next activity in the flow to execute based upon the glucose level. The condition of a flow is attached to the sequence

flow exiting the gateway. How the egress (diverge) sequence flows out of a gateway is assessed by the gateway itself.

Shown below in [Figure 5](#) ("Pools, Gateway and End Events") is a diverging exclusive gateway and a parallel gateway above. The diverging exclusive gateway (see page 286 of BPMN spec) shows a situation where only one output sequence flow will be traversed; exclusivity may be shown as an empty diamond or a diamond containing an "x." With gateways, all possible pathways provided must be exhaustive; otherwise, the clinical flow may deadlock. Here the clinical flow will either "Check Out" the patient, "Give Referral" to the patient, or "Send (the patient) to Hospital" determining the sequence flow. The decision on what the patient should do was determined in the "Decide Treatment Plan" activity.

The Parallel gateway above shows "splitting" the flow into two parallel, independent flows. There are six different types of gateways as shown in the [BPMN OMG specification](#) page 287.

3.2.5. Data Object

Data Objects (see [Figure 4](#) and pages 27 and 221 of the [BPMN OMG specification](#)) identify data that is sent or received by Tasks or Activities. A Data Object may be passed through a Message among Pools. They may be assessed to affect the flow of a pathway. In addition, Data Objects can be created and updated as part of an Activity.

3.2.6. Connectors – Sequence, Message Flows and Associations

Sequence and Message Flows (see page 32 of [BPMN OMG specification](#)) are the two types of connectors within BPMN processes that are part of the execution semantics. They affect the flow and sequence execution of the process (see [Figure 5](#)). *Sequence Flows* are solid lines that act as the glue between nodes (Activities, Events and Gateways) within the clinical flow. They visually depict the order in which a flow may progress (i.e., the Sequence). As noted earlier, they may only be used within a Pool.

Message Flows are dashed lines that show the flow of information between processes contained within separate Pools. They show the movement of information and synchronizing events among Participants. They depict the sending or receiving of data or signals between Events or Activities in separate Pools.

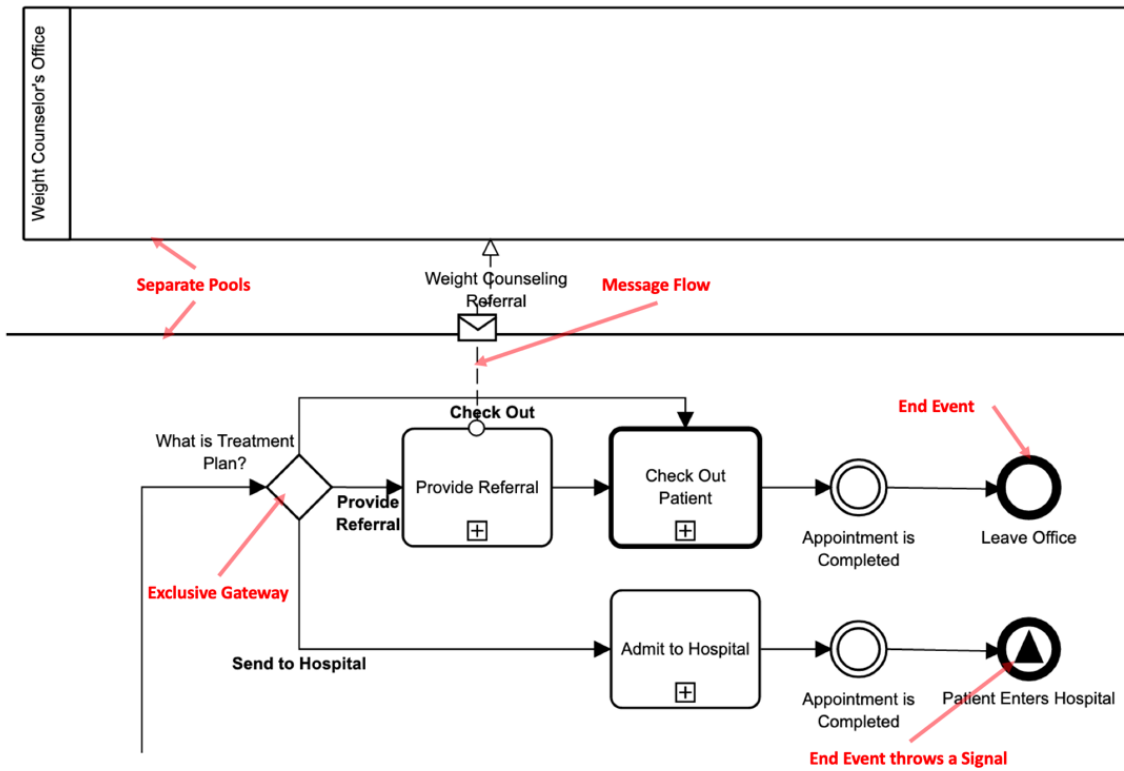


Figure 5 – Pools, Gateway and End Events

Associations (see pages 27 and 220 of [BPMN OMG specification](#)) are dotted-line connectors that provide visual information to the reader. They are used to link annotations to any element within a process. Data Associations, on the other hand, are directional-dotted line connectors used to connect Data Objects to Activities. The execution semantic of Data Association is to provide the input or output data mapping applied based on the direction of the arrow on the Data Object.

3.3. Case Management Modeling Notation (CMMN) for Hello Patient

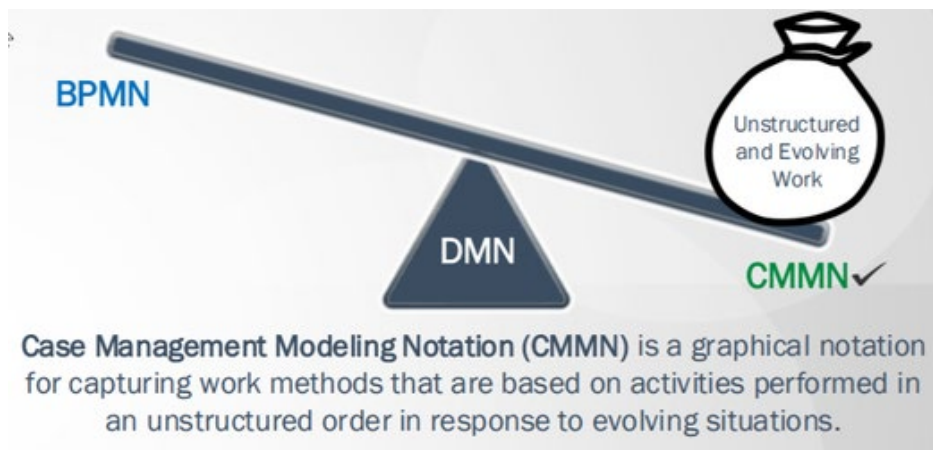


Figure 6 – CMMN Outweighs BPMN

Certain clinical pathways and activities can be prescribed (deterministic) at design time – during the process of designing the model, such as making a doctor's appointment for the flu – but other processes are more *ad hoc* and non-deterministic. These *ad hoc* processes may be due to sudden and unexpected events that occur in the real world or due to known events that are unpredictable in their timing. Often the environment requires care providers to adapt to unexpected, emerging and/or changing environmental conditions (e.g., no fetal heartbeat is observed during a regular prenatal care exam). As such, the traditional method of representing clinical pathways using BPMN is difficult at best. An agile *ad hoc* environment cannot be easily represented with BPMN and requires an adaptive "case management" style of representation. This is the role of CMMN: specifying clinical responses to *ad hoc* events based on the state of the particular case. CMMN allows real-time response to the unfolding of sudden and unforeseen events in the form of flexible choices/selection of activities as the care provider determines necessary. The reader will be directed to the OMG Case Management Modeling Notation (CMMN) version 1.1 (<http://www.omg.org/spec/CMMN/1.1/PDF>) for more details.

The following discussion uses the Hello Patient CMMN example shown in Appendix E . As in the BPMN example, this example is for illustration purposes and is not necessarily sufficient nor complete enough to represent a patient encounter. Take a moment to look back at the BPMN model in Figure 89 Hello Patient BPMN. Note the Case Activity called "Perform Examination" in Figure 7 ("BPMN – Perform Examination").

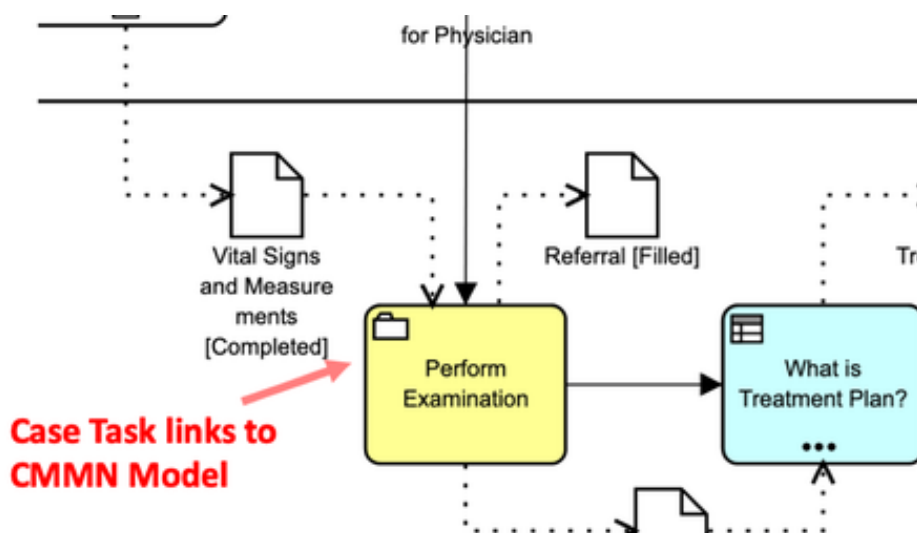


Figure 7 – BPMN Perform Examination

This is where BPMN turns over the representation of the clinical pathway to CMMN to handle the adaptiveness of performing an exam on a patient. This Activity links to a Case Plan Model within CMMN.

3.3.1. Case Plan Model

The Case Plan (sometimes called the Case) is represented graphically as a folder containing all the relevant CMMN constituents of the case model depicting the situation to be modeled (see page 59 of the [CMMN OMG Specification](#)). All the pertinent elements (sometimes referred to as plan items) of a plan are contained within the case. A case typically shows Events that may happen, the Tasks performed in response to those Events, Decisions that may need to be made, "sub-cases," Milestones that may be reached in the course of handling the Cases, and Case File Items that represent information used during processing of the Case.

3.3.2. Tasks

A Task represents a unit of work (see [Figure 8 CMMN Tasks](#) and page 43 of the [CMMN OMG Specification](#)). There are four types of CMMN Tasks: *Human Tasks* performed by a care provider; *Case Tasks* used to call other tasks; *Process Tasks* used to initiate a business process; and *Decision Tasks* used to make a decision. *Human Tasks* can be blocking and non-blocking. A blocking Human Task is one that awaits the intervention and completion by a human. A non-blocking Human Task is one that executes once initiated and will complete immediately. Human Tasks can also be *Discretionary*, indicating that a person may or may not choose to add the task to the plan at run time vs. a *Required* task that must be performed (see [Figure 8 CMMN Tasks](#)).

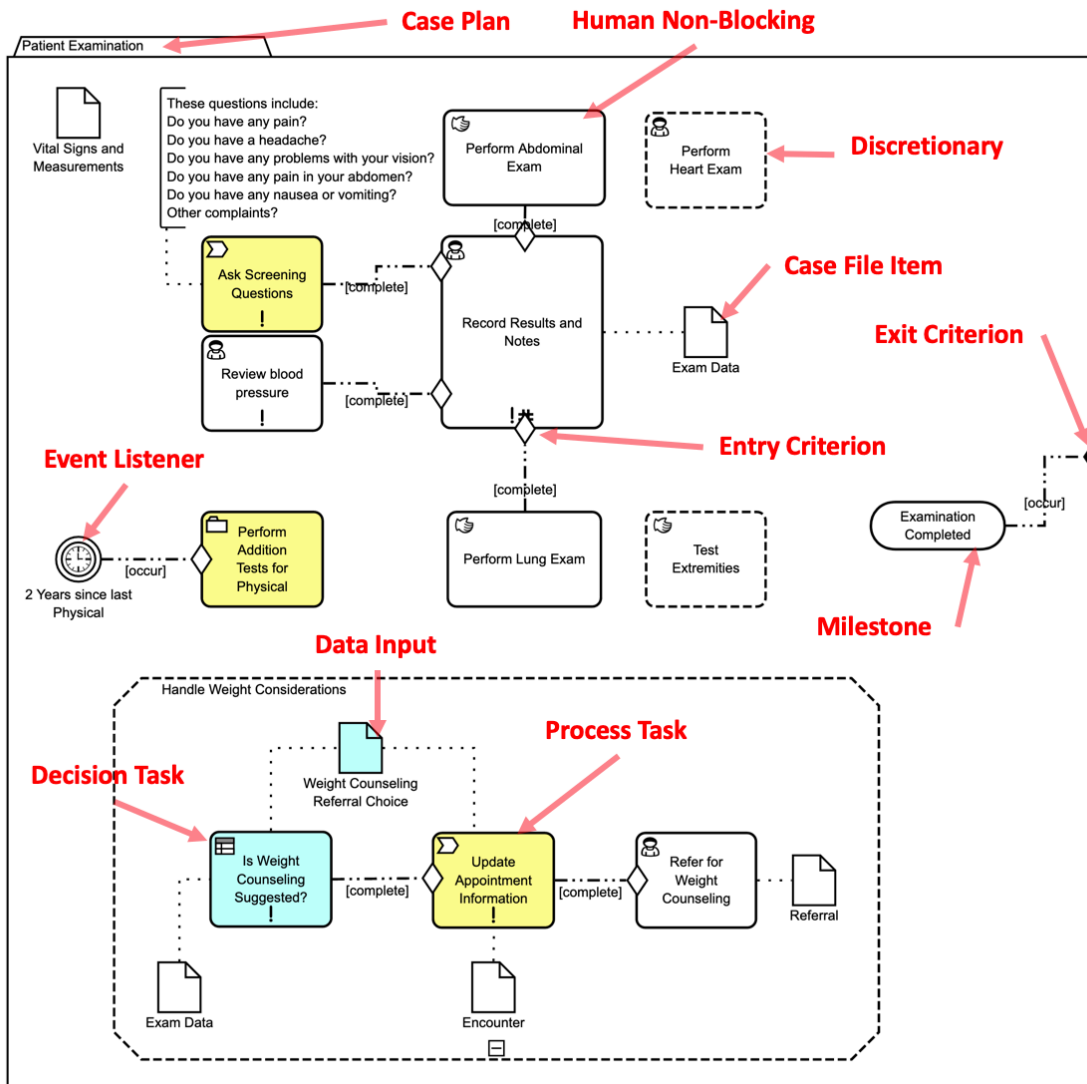


Figure 8 – CMMN Tasks

3.3.3. Milestone

A Milestone is a Plan Item that represents an achievable target or goal. Milestones are rectangle shape with half-rounded ends that are defined to enable evaluation of the progress of a Case. No work is directly associated

with a Milestone but completion of a set of Tasks or the availability of key deliverables (information in the Case File) typically leads to achieving a Milestone. A Milestone may have zero or more entry criteria, which define the condition when a Milestone is reached (see page 28 of the [CMMN OMG specification](#)).

3.3.4. Entry and Exit Criterion

Plan Items can have sentries (or guards) marking the entry or exit to a Plan Item. Sentries are shown as small diamonds attached to other Plan Items. A non-filled diamond marks an Entry Criterion and a solid diamond denotes an Exit Criterion (see page 61 of the [CMMN OMG specification](#)). Criterion are used to describe when a task, stage, or milestone should be available for execution (entry criteria) or when a case (case plan), stage, or task should terminate normally (exit criteria).

An entry criterion describes the condition that must be satisfied for the stage, task, or milestone to be available for execution. Stage, task, or milestones without entry criteria will be available for execution as soon as they are created. The entry criteria can be placed anywhere in the border of the stage, task, or milestone.

An exit criterion is like an entry criterion, but it is used to stop working on the stage, task, or case (case plan) when it is satisfied.

3.3.5. Case file (item)

A Case file (also called a case folder) is contained in a case. It contains Case file items that the care providers have access to during the execution of a case. Care providers can add, remove, and modify case items in the case file (see page 60 of the [CMMN OMG specification](#)). Case file items can be used to represent a variety of structured and unstructured data "types," e.g., data values in a database, a row in a database, a document, a spreadsheet, a picture, a video, an element in a FHIR resource, or a Clinical Information Modeling Initiative (<https://www.opencimi.org/>) structure. In addition to basic data, case file items can also represent containers such as directories, folders, sets, stacks, or lists.

3.4. Hello world Doctor Visit Decision Modeling Notation (DMN)

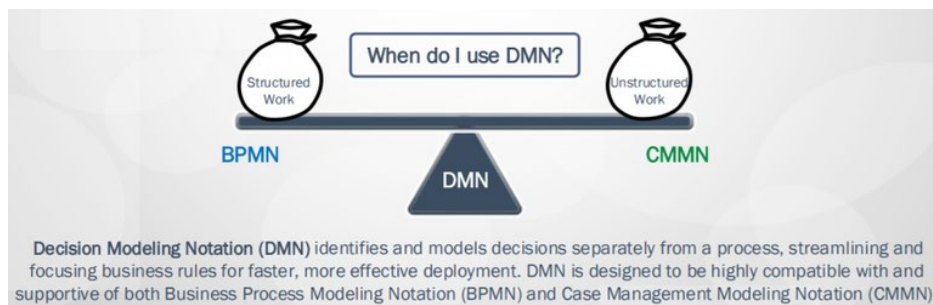


Figure 9 – When to Use DMN

Decision Model and Notation (DMN) is a modeling notation for graphically specifying decisions. It is used by care providers designing clinical decision models, technical developers automating the decisions in processes, and business people who manage and monitor those decisions. Its purpose is to provide the elements required to model decisions in diagrams, accurately defined by business analysts, and optionally automated. In addition, it is also designed to be usable alongside BPMN and CMMN models. The current version of the Decision Modeling and Notation can be found at this link: <http://www.omg.org/spec/DMN/1.1/PDF>. See Figure 10 ("Decision Requirement Diagram") for an example of a DMN model.

3.4.1. Decision

Decisions encapsulate decision logic that is applied to a collection in inputs to ascertain the appropriate output. They denote the act of determining an output from a number of inputs, using decision logic that may reference one or more Business Knowledge Models. The logic can be expressed as a decision table, a FEEL literal expression, relationship table, and/or boxed expression. See page 20 of the DMN specification for further information.

3.4.2. Business Knowledge Model

A Business Knowledge Model (BKM) (see [Figure 10](#)) is a function encapsulating business knowledge. The logic of the encapsulated business knowledge can be expressed using a relationship table, a FEEL literal expression, a decision table, a Java Class, and/or an analytical model captured in a PMML analytic model. BKMs are essentially reusable decisions.

3.4.3. Knowledge Source

Knowledge Sources (see [Figure 10](#)) help document the authority or source of the logic within a decision. Knowledge Sources are informational only and have no effect on the execution of the model by a computer if the models were executed. They are used to help add clarity for the reader of the models. They depict the authority for a Business Knowledge Model or Decision. The knowledge source that impacts a Decision is linked via an Authority Requirement.

3.4.4. Information Requirement

An Information Requirement (see [Figure 10](#)) depicts data or a decision output being used as one of the inputs of a decision. Decisions are linked to other decisions shown using a solid line with a solid arrow head. The line represents an output from one Decision becoming an Information Requirement to another Decision (see [Figure 10](#)).

3.4.5. Authority Requirement

An Authority Requirement denotes the dependence of a DMN Decision Requirement Diagram (DRD) (see [Figure 10](#)) element on another DRD element that acts as a source of guidance or knowledge.

3.4.6. Annotation

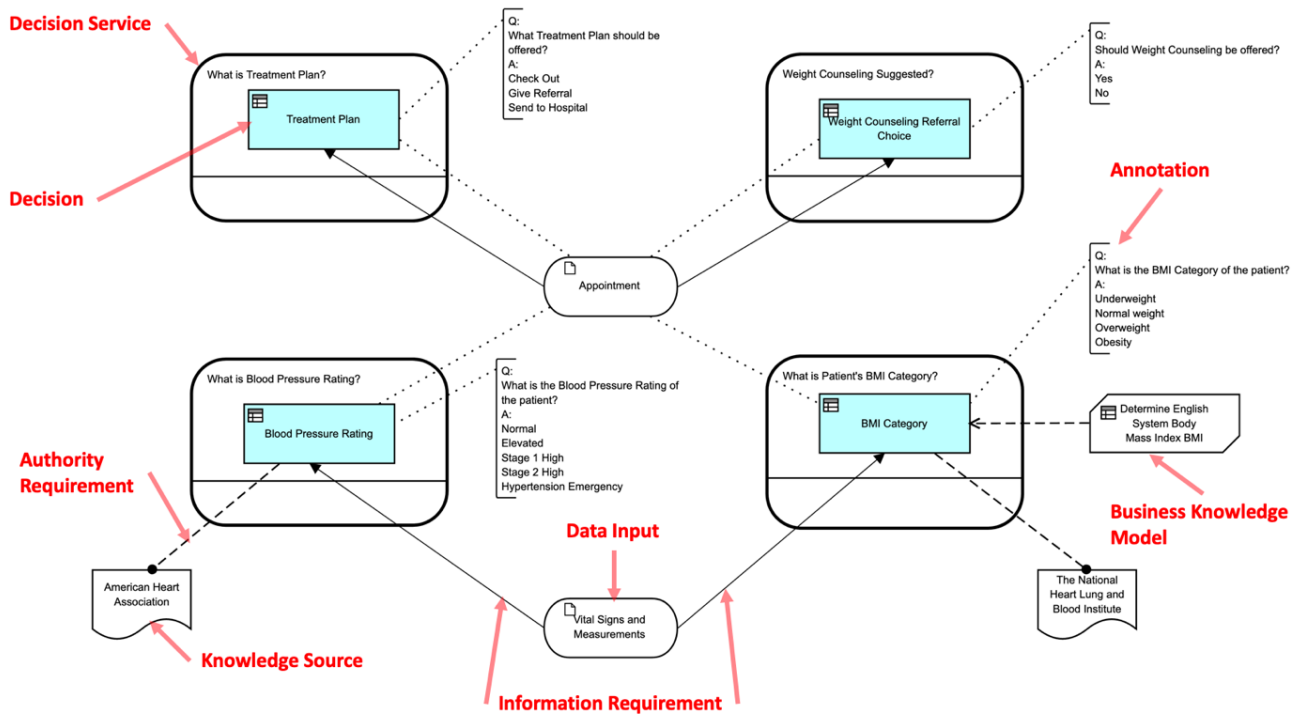


Figure 10 – Decision Requirement Diagram (DRD)

An Annotation (see below) is an explanatory text or comment added to a diagram to provide clarity for the reader and has no impact on the execution of the decision logic.

3.4.7. Hit Policy

A decision table normally has several rules generally depicted as rows. As a default, rules do not overlap. If rules overlap – meaning that more than one rule may match a given set of input values – a "Hit Policy" indicator is required to recognize the table type and unambiguously understand the decision logic. The Hit Policy can be used to check correctness at design-time. The Hit Policy specifies what the result of the decision table is in cases of overlapping rules (i.e., when more than one rule matches the input data). For clarity, the Hit Policy is summarized using a single character in a particular decision table cell (see Figure 11, "Decision Table"). The character is the initial letter of the defined Hit Policy; possible types of Hit Policies are Unique, Any, Priority, First, Collect, Output order or Rule order. See page 82 of the [OMG DMN specification](#) for a complete description of the Hit policies.

3.4.8. Inputs Data

An input data element denotes information used as an input by one or more Decisions. See page 78 of the [OMG DMN specification](#).

3.4.9. Output

Outputs are the values that will be set if the corresponding row conditions are evaluated as true. It is the output value of the Decision. See page 78 of the [OMG DMN specification](#) .

3.4.10. Condition

A Condition (see [Figure 11](#)) is a cell within a decision table representing a possible "value" of a particular input parameter (or column of the table). It is the condition that will be evaluated against the respective input value to determine truthiness. If the actual input matches the cell, then the cell is evaluated as true. The set of conditions in a particular row represent the antecedent of the clinical rule. Note that a '-' within a cell means that the input for this cell is irrelevant. See page 80 of the [OMG DMN specification](#) .

3.4.11. Row

Rows (see [Figure 11](#) below) within a table represent a family of business rules. Each row represents one complete rule with a condition(s) (antecedent) and a then (output) if the conditions evaluate to true. All conditions within a row must be true for the row to be true.

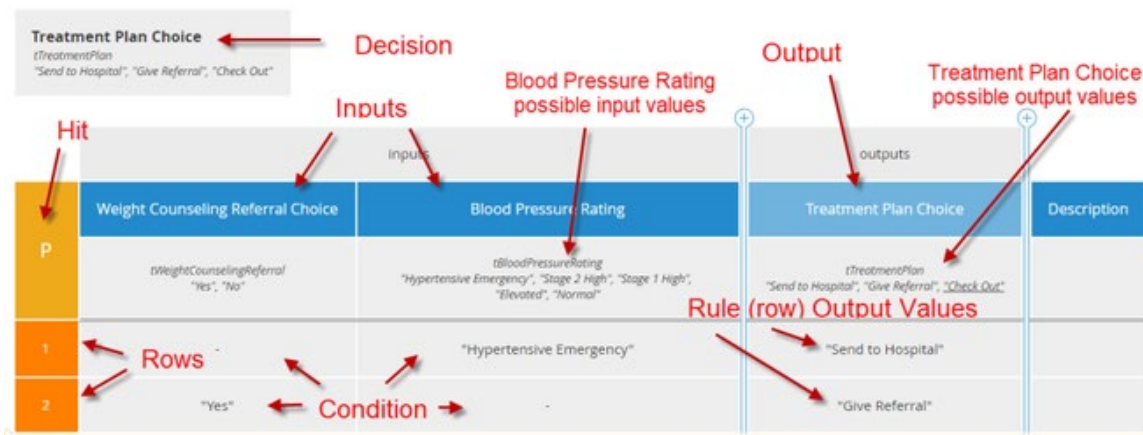


Figure 11— Decision Table

4. Producing Models

This Field Guide's Introduction defined clinical pathways, in general, and Shareable Clinical Pathways, specifically. This section of the Field Guide provides guidelines; that is, the methods and styles for Shareable Clinical Pathways Producers to develop consistent, usable, and shareable clinical pathway definitions.

4.1. Qualities of Shareable Clinical Pathways

The development of valid and usable Shareable Clinical Pathways is challenging. This Field Guide provides the method and style for creating consistent and valid models, defined in detail in sections below. In addition to the detailed method and style, there are meta-level patterns and principles that should be followed. These are described in the following two sections.

Important Characteristics for Shareable Clinical Pathways	
Semantic Clarity	Pathways must be defined in such a way that they are semantically clear and precise. Clear definitions of information element(s), precise and disambiguated in the use of those element(s).
A Complete Solution	The pathway is complete and there is always a hand off or terminal end point.
Focused Pathways	The pathway must be specific and targeted (focused). Vague and/or large-scale pathways cannot be easily reused or shared.
Flexibility by Design	Pathways explicitly incorporate flexibility mechanisms into the process at design time and are not decisions for the consumption process.

Table 1 Shareable Clinical Pathway Characteristics

Good Shareable Clinical Pathway Principles

The following principles should be incorporated into the modeling of shareable clinical pathways components to ensure the characteristics of precision, clarity, and reusability.

Shareable Clinical Pathway Models and Components Need to be Extensible but also Durable

Models that are extensible and durable will be the most easily shared, used and reused clinical pathways. In the context of a pathway, an organization does not need to modify the flow of events and logic to use the pathway but can customize the flow by extending components of the flow to match its environment.

Using the example of a pathway supporting the treatment of an ankle injury, there would be a goal to reduce swelling. If the pathway defined an event: "Apply Ice Cubes," and an organization used a "Cold Pack" rather than "Ice Cubes," the organization would need to modify the pathway to say, "Apply Cold Pack," breaking this principle. If the pathway defined the event as "Apply Cold Treatment," the organization could extend the event locally by adding "Apply Cold Pack" if needed therefore taking advantage of the benefit of the Shareable Clinical Pathway. The benefits of Shareable Clinical Pathways are lost if each organization needs to continually and materially modify pathways.

Shareable Clinical Pathway Model Components Need to Exhibit "Design by Contract"

Defining a component for use within a shareable pathway: There is an intrinsic need to design by contract and as such the use of such a derived component meet the requirements for such a contract.

Design by contract becomes particularly important in working with decision points within the workflow. The workflow must rely on all DMN returning the same "1 to many" results regardless of the localization of the DMN. The workflow cannot be designed in such a way that it needs to integrate the localization of the DMN to continue processing. Take, for instance, a sample decision point in a shareable workflow determining "Is ankle broken" returning two decisions "YES/NO." It might make sense for a localization to have a response of "MAYBE", but this breaks this principle because the shareable workflow is expecting "YES/NO." An appropriate design would have the shareable workflow expect "YES/NO/MAYBE" as a result. Some localizations would never return MAYBE but the principle is upheld.

Shareable Clinical Pathway Model Components Need to Define Generalized Behaviors

Applied to the modeling of clinical pathways, events within a clinical pathway need to be designed in such a way that their verbiage is not dependent on the context of execution; rather, they are applicable to many contexts. If, instead of “Apply Cold Treatment,” the pathway stated, “Apply Cold Treatment to Left Ankle,” it would clearly limit the use of such an event to pathways dealing specifically with left ankle injuries. This might seem trivial in nature but highlights the need to define reusable events and decisions as a cornerstone to providing a framework of shareable clinical pathways. If the decision or event cannot be used in multiple pathways without modification, it does not follow this principle.

Shareable Clinical Pathway Models Need to Provide a Ubiquitous and Pervasive Perspective

Pervasive computing is a natural extension of the existing computing paradigm. In the pervasive computing vision, software agents, services, and devices are all expected to seamlessly integrate and cooperate in support of human objectives: anticipating needs, negotiating for service, acting on our behalf, and delivering services in an anywhere, any-time fashion. The perspective of the Shareable Clinical Pathway needs to build upon the notion of ubiquitous and pervasive computing to provide a complete and implementable workflow.

4.1.1. Project High Level Best Practices

This section is not to be intended to provide full guidance about project management issues. It is just intended to provide some of the key actions that will support the development of Shareable Clinical Pathways. The major project management activities include:

- Performing a stakeholder analysis of the project (e.g., Responsible/Accountable/Consulted/Informed, or RACI);
- Identifying one or more subject-matter experts (SMEs) familiar with the clinical pathway topic who will commit to the project;
 - This includes SMEs who will validate the Clinical Pathway models upon completion;
- Identifying one or more Modelers familiar with the BPM+ Standards who will become the Producers of the Shareable Clinical Pathway models; and
- Identifying all relevant documentation or previous modeling efforts for a clinical pathway or related medical procedure and making them available for the SMEs and Producers to review.
 - This would include relevant ontologies or glossaries.

4.1.2. Methodology for Clinical Pathway Modeling

In this section we have described the basis for a methodology that supports the development of Shareable Clinical Pathways that are indeed shareable and to some extent automated. As with most methodologies, there are some explicit heuristics to which conforming models must comply.

This is the general methodology for creating Shareable Clinical Pathways that is reusable, executable, and compliant with this Field Guide:

1. Define the scope of the Shareable Clinical Pathway (which is the topic). This will help the Producers of the models to stay on topic and not add extraneous activities or activities that belong in other Shareable Clinical Pathways.
 - a. What are the different triggers of the pathway?
 - b. What is the ending point?
 - c. What are the goals?

- d. What is the context?
 - This type of information should be captured and defined as metadata for the pathway Knowledge Model.
 - ❖ *Note that there are multiple approaches to a scope definition, including – but not limited to – Business Model Canvas²; Value Proposition Canvas³; Inputs, Guides, Outputs, Enablers (IGOE)⁴. This Field Guide does not recommend one approach over another.*
2. Develop a high-level 5WH Model.
 - a. This is the Who, What, When, Where, Why, and How (5WH) of the Clinical Pathway “(see more information about the 5WH model below).
 - b. Create relationships between the 5WH Model elements (e.g., Assign the Performers for the Activities).
 - c. This will serve as the Shareable Clinical Pathway Glossary.
 3. Do Modeling. Create the first draft of the models based on content captured in the 5WH model.
 - a. Partition HW5 Activities as appropriate.
 - b. Create the Root Case (using the name of the Shareable Clinical Pathway).
 - c. Create Process (BPMN) and Case (CMMN) Models from the 5WH Model Activities.
 - d. Create Decision Models (DMN) from the 5WH Model Activities.
 - e. Create a Shareable Clinical Pathway Architectural Scope Diagram as needed.
 4. Iterate on the three types of models until they are all executable.
 - a. Utilization validation techniques, such as: review by SMEs, including model walk-throughs and site visits; application of the method and style of this field guide; and simulation, if available.
 - b. Employ model decomposition as necessary to improve the organization and understandability of the set of models.
 - c. Synchronize the elements of the three types of models with the Clinical Pathway Glossary as they are being developed.
 - d. Create or utilize a Process Architecture of the healthcare organization.
 - Define relationships between the Clinical Pathway models and a Process Architecture.
 5. Perform validation with external healthcare professionals who were not involved in the development of the Shareable Clinical Pathway. They should validate the models based on Quality & Applicability.

4.2. High-Level Modeling Best Practices

Too often, business practices assume that health delivery is being conducted within one care location/institution, placing limitations on the processes and ultimately adversely affecting patient care that naturally spans organizations and sites. Thus, the Shareable Clinical Pathway Models should highlight the distributed nature of healthcare. That is, many independent organizations are often involved in the care of an individual patient. For example, a patient may see a doctor who is part of an independent group, then go to an imaging center for a PET scan, then go to a lab to have blood drawn and then analyzed.

The following is an outline of the best practices that should be followed to model the distributed nature of Shareable Clinical Pathways.

² https://en.wikipedia.org/wiki/Business_Model_Canvas

³ <http://www.marketingteacher.com/value-proposition-canvas/>

⁴ <https://www.brcommunity.com/articles.php?id=b634>

1. BPMN Collaborations (a model with two or more Participants) should be used to show the communication among separate entities involved in the Shareable Clinical Pathway.
 - a. Each Participant in a Collaboration is represented by a separate BPMN Pool.
2. In a Collaboration, one of the Pools will be the focus of the diagram and the details of the Process within the Pool will be complete. It will be the "main" Pool.
 - a. The Processes within other Pools in the Collaboration may be undefined (i.e., the Pool is a "black box") or may be partially defined to show only the Tasks that send and receive messages (i.e., a "public" Process in BPMN).
 - b. It is recommended that the external participant Pools display the public Process as it interacts with the main Pool.
 - c. However, if the activities of the external participant are critical to the best practices defined by the Shareable Clinical Pathway, then the entire Process (all activities) should be modeled in the Pool of that participant.
3. A BPMN Choreography Diagram or Conversation Diagram is useful to isolate the interactions involved between all the participants involved in the Shareable Clinical Pathway, especially when these interactions become complex. The method and style for developing Choreography and Conversation models will be presented in a future version of this Field Guide.

4.3. Shareable Clinical Pathway Models

This Field Guide defines the content and the style for developing the knowledge artifacts that comprise a Shareable Clinical Pathway. In this context, a Shareable Clinical Pathway contains a set of these related models:

1. A Library/5WH Model
 - a. In particular, the Artifacts (Data Items) that define the "Situational Data"
2. A Knowledge Model Diagram
3. Metadata about the Knowledge Model (Shareable Clinical Pathway)
4. BPMN Process Model(s)
5. CMMN Case Model(s)
6. DMN Decision Model(s)

The following sections will define the method and style for developing these models.

4.3.1. Clinical Pathway Library/5WH Model

The 5W approach (or Who, What, When, Where, and Why), has been applied to analysis since ancient times⁵. The Five Ws and one H (How) have been applied to quality stories in journalism for more than 100 years. This is the source of the "5WH" label for the model, which also has been used in the healthcare domain⁶.

In the context of developing a Shareable Clinical Pathway, the 5WH model is the official list of Activities, Actors, Artifacts, Events, Systems (non-person resources), and Goals that are used in the Models. For the purposes of

⁵ Edwin Carawan, "What the Laws have Prejudged: Παραγραφή and Early Issue Theory" in Cecil W. Wooten, George Alexander Kennedy, eds., *The orator in action and theory in Greece and Rome*, 2001. ISBN 90-04-12213-3, p. 36.

⁶ The Five Ws for Information Visualization with Application to Healthcare Informatics. IEEE Transactions on Visualization and Computer Graphics, Vol. 19, No. 11, November 2013.

Shareable Clinical Pathways, the list of 5WH items is extended to define the relationships between the items. That is why it is also referred to as a model.

The collection of the 5WH model items also serves as a terminology reference for the elements of the behavioral models developed for a Clinical Pathway. This is the source of the "Library" label for the model.

Many of the items that appear in the Library/5WH Model will appear in multiple diagrams that define the Clinical Pathway. The Library/5WH Model provides the naming and format of these items as they are used in the individual models, ensuring consistency across the models and especially for complex Clinical Pathways that could be composed of dozens of interrelated models.

Cross-Clinical Pathway Library/5WH Models or organizational Models can be developed to help with consistency across a larger scope of models.

The Library/5WH model is the first model developed in a Shareable Clinical Pathway project.

1. The model includes these elements:
 - a. Activities, Actors, Artifacts, Events, Systems (non-person resources), Goals
 - b. That is, the: How, Who, What, When, Where, Why
2. If there is a larger scope Glossary/5WH Model available, then many elements, such as Actors, Artifacts, etc., can be used in the local Glossary/5WH Model for the Clinical Pathway.
3. The Library/5WH Model elements will be organized into:
 - a. Groups (e.g., Activity Groups, Actor Groups, Data Groups, etc.)
 - The Groups will contain Items.
 - b. Items (e.g., Activity Items, Actor Items, Data Items, etc.)
 - The Items will be listed within a Group.
 - Items can be nested within the Group (i.e., they can create sub-structures).
4. The Groups and Items will map to various model elements within the BPM+ models.
5. Library/5WH Model elements can be linked to external references and ontologies, as appropriate.
 - a. If no external reference exists for a key element of the Clinical Pathway (e.g., a data artifact), then this gap should be noted, and the proper community engaged to fill that gap.
6. The relationships among the elements can be defined (e.g., the standard actors who perform an activity or the required artifact inputs/outputs to an activity).
7. The Library/5WH Model will serve as the basis for creating the diagrams for the Clinical Pathway. It will also serve as the vocabulary/glossary of the Clinical Pathway and should be maintained throughout the project.
 - a. To provide the most complete initial diagrams and to make the maintenance easier, it is best to make the Library/5WH Model as complete as possible before starting the diagramming.
 - b. There may be substantial revision of the Clinical Pathway diagrams after they are first created from the content of the Library/5WH Model. Ensure that the Library/5WH Model is maintained throughout the development of the Clinical Pathway Model.
 - In particular, the Artifacts (Data Items) of the Library are the most important elements to maintain. All of the BPM+ models contain Data Items and they should match the Data Items stored in the Library.

- We will refer to the Artifacts in the Library as the "Situational Data" of Shareable Clinical Pathway (more on this below).

The next few sections define the style and modeling conventions for the types of elements within a Library/5WH Model. The Library/5WH model can be created with various tools, including Excel. The images provided in this Field Guide include examples with Excel and with other vendor implementations of the Library/5WH model.

It should be noted that the development of the 5WH model will continue throughout the development of the Shareable Clinical Pathway. There will be an early version of the 5WH model created while doing the initial discovery and analysis of the Clinical Pathway information and through the interviews of the SMEs. When the BPM+ diagrams are developed, then the structure and organization of the 5WH model could be significantly modified. The sections below describe the 5WH elements and how the elements of the BPM+ diagrams will impact their formats.

Cross-Clinical Pathway Library/5WH Models or organizational Models can be developed to help with consistency across a larger scope of models.

The Library/5WH model is the first model developed in a Shareable Clinical Pathway project.

1. The model includes these elements:
 - a. Activities, Actors, Artifacts (Data), Events, Systems (non-person resources), Goals
 - b. That is, the: How, Who, What, When, Where, Why
2. If there is a larger scope Library/5WH Model available, then many elements (e.g., such as Actors, Artifacts, etc.) can be used in the local Library/5WH Model for the Clinical Pathway.
3. The Library/5WH Model elements will be organized into:
 - a. Groups (e.g., Activity Groups, Actor Groups, Data Groups, etc.)
 - The Groups will contain Items.
 - b. Items. (e.g., Activity Items, Actor Items, Data Items, etc.)
 - The Items will be listed within a Group.
 - Items can be nested within the Group (i.e., they can create sub-structures).
4. The Groups and Items will map to various model elements within the BPM+ models.
5. Library/5WH Model elements can be linked to external references and ontologies, appropriate.
 - a. If no external reference exists for a key element of the Clinical Pathway (e.g., a data artifact), then this gap should be noted, and the proper community engaged to fill that gap.
6. The relationships among the elements can be defined (e.g., the standard actors who perform an activity or the required artifact inputs/outputs to an activity).
 - a. The Library/5WH Model will serve as the basis for creating the diagrams for the Clinical Pathway. It will also serve as the vocabulary/glossary of the Clinical Pathway and should be maintained throughout the project.
 - To provide the most complete initial diagrams and to make the maintenance easier, it is best to make the Library/5WH Model as complete as possible before starting the diagramming.
 - There may be substantial revision of the Clinical Pathway diagrams after they are first created from the content of the Library/5WH Model. Ensure that the Library/5WH Model is maintained throughout the development of the Clinical Pathway Model.

- In particular, the Artifacts (Data Items) of the Library are the most important elements to maintain. All of the BPM+ models contain Data Items and they should match the Data Items stored in the Library.
- We will refer to the Artifacts in the Library as the "Situational Data" of Shareable Clinical Pathway (more on this below).

The next few sections define the style and modeling conventions for the types of elements within a Library/5WH Model. The Library/5WH model can be created with various tools, including Excel. The images provided in this Field Guide include examples with Excel and with other vendor implementations of the Library/5WH model.

It should be noted that the development of the 5WH model will continue throughout the development of the Shareable Clinical Pathway. There will be an early version of the 5WH model created while doing the initial discovery and analysis of the Clinical Pathway information and through the interviews of the SMEs. When the BPM+ diagrams are developed, then the structure and organization of the 5WH model could be significantly modified. The sections below describe the 5WH elements and how the elements of the BPM+ diagrams will impact their formats.

Cross-Clinical Pathways Library

1. If there is a Cross-Clinical Pathway Library, then items in the larger Library that match items in the local, Clinical Pathway Library should be used in the Clinical Pathway Library.
2. Once the Clinical Pathway has been completed, the local Library for the Clinical Pathway should be reconciled with the Cross-Clinical Pathway Library.

How – Activities

Activities represent the "how" aspect of the Clinical Pathway. This is the work and/or general behaviors that are performed for the Clinical Pathway.

1. The work of a Shareable Clinical Pathway will usually be divided into multiple 5WH.

Activity Groups

These Activity Groups can be hierarchically decomposed and linked together.

1. Each Activity Group represents a separate cohesive portion of work, which will be defined with a BPMN Process or a CMMN Case.
 - a. The highest-level Activity Group will be a CMMN Case Model. See more on this below.
 - b. An Activity Group will have a list of Activity Items that represent the Tasks and Sub-Structure elements of that BPMN Process or CMMN Case.
2. It is up to the Clinical Pathway Producer to determine which Activity Groups will be modeled with a BPMN Process and which will be modeled with a CMMN Case.
 - a. An SME should be able to verify that a group of Activity Items are performed in a general sequence or in an unstructured manner.
3. The figure below displays two three Activity Groups for the Hello Patient example. The two Activity Groups on the right was used to generate a CMMN models and the Activity Group on the left was used to generate a BPMN model. The differences among the three Activity Groups are not easily apparent until the diagrams are created from their content.

Manage Patient Visit #P	Patient Examination #C	Hello Patient #C
Check In Patient	Ask Screening Questions	Manage Patient Visit (L)
Check In Patient	Review blood pressure	
Take Vital Signs (S) ->	Perform Abdominal Exam	
Patient Examination (L) ->	Perform Lung Exam	
What is Treatment Plan? (L)	Perform Heart Exam	
Update Appointment Record	Test Extremities	
Record Examination Results/Update History	Handle Weight Considerations (S) ->	
Provide Referral	Record Results and Notes	
Choose Provider	Perform Additional Tests for Physical (L) ->	
Check Out Patient		
Check Out Patient		
Admit to Hospital		
Admit to Hospital		

Figure 12 – Examples of Library/5WH Model Activities

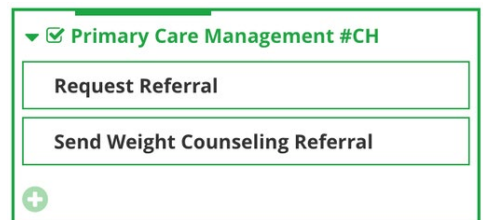
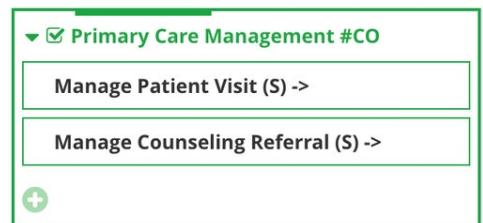
See the next sections about activity types and naming activities.

- ❖ *Note: For more guidance on determining whether an Activity Group should be a Process or a Case, see the section below titled, "Choosing between BPMN and CMMN."*

Specifying Activity Types

The Activity Groups in the Library will be realized as Processes, Cases, Sub-Processes, Stages, and Tasks in the behavioral models of the Shareable Clinical Pathway. However, just naming the Activity Group in the Library doesn't always indicate how it will be realized in a model. Thus, we recommend that Activity Group names are appended with markers to indicate their types:

- After the Producer has determined an Activity Group's type, then the activity should be annotated to show that type.
 - BPMN Processes, including Sub-Processes with their own Activity Group, should be annotated with "#P" to show they are Process types of activity (see figure at right).
 - In some cases, a Sub-Process – because of its size and/or complexity – will be placed in its own separate Activity Group. A Sub-Process is, in fact, a Process so it will also be marked with the "#P." It will be possible to derive the fact that it is a Sub-Process through activity relationship markers as defined below.
- CMMN Cases, including Stages with their own Activity Group, should be annotated with "#C" to mark that they are Case types of activity (see figure at right).
- BPMN Collaborations should be annotated with "#CO" (see figure at right).
- BPMN Choreographies should be annotated with "#CH" (see figure at lower right).
- Activity Groups that have not yet been designated as a type of model will not have a hashtag marker and will be considered undefined.



- ❖ *Note: Activity Groups may change type during the iterative modeling of a Shareable Clinical Pathway. For example, a Process may be transformed into a Case. Thus, the name and the marker for the Activity Group may change during the life of Shareable Clinical Pathway development project.*

Activity Group Types and the Knowledge Model Diagram

The Knowledge Model Diagram will include the activities that are defined in the Library. That is, the hashtag marker for a Library activity will determine the shape of the element in the Knowledge Model diagram. This will be illustrated in the section on the Knowledge Model Diagram (see [below](#)).

Naming Activity Groups and Items

There are many possible patterns for naming Activity Groups and other Library elements; however, we recommend a specific pattern for naming the types of Activity Groups identified in the section above. The following pattern will provide a consistent method for naming Activity Groups within a Shareable Clinical Pathway.

- BPMN Processes should be named in a verb-noun format: “Manage Patient Visit,” for example.
- BPMN Collaborations should be named in a noun format: e.g., “Primary Care Management.”
 - ❖ *Note that Business Architecture higher-level Functions and Capabilities should also be named in a noun format.*
- BPMN Choreographies should be named in a noun format: e.g., “Primary Care Management.”
 - ❖ *Note that Collaborations and Choreographies will often share the same name since they provide different views of the same set of Message exchanges.*
- CMMN Cases should be named in a noun format: e.g., “Patient Examination.”

The following pattern will provide a consistent method for naming Activity Items within a Shareable Clinical Pathway.

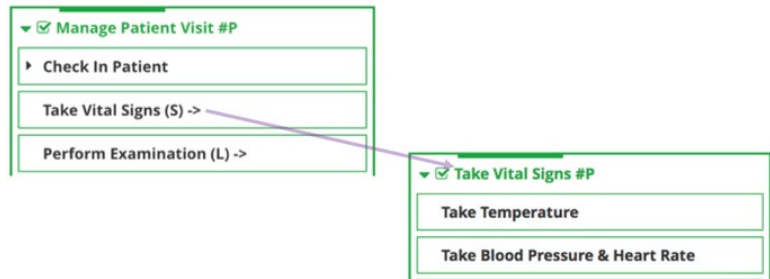
- BPMN Tasks, Sub-Processes, and Call Activities (Linked Processes) should be named in a verb-noun format: e.g., "Update Appointment Record."
- CMMN Tasks should be named in a verb-noun format: e.g., "Ask Screening Questions."

These naming patterns should apply to the BPMN Processes and CMMN Cases that are part of the Shareable Clinical Pathway.

Specifying Activity Groups Relationships

The Processes and Cases in a Shareable Clinical Pathway comprise a network of behaviors that are linked together. We recommend that these relationships are also marked within the Library:

- The hierarchical network of the Clinical Pathway is created through two types of relationships:
 - Sub-Activities; and
 - Links to independent Activities.
- In each type of relationship, there will be an Activity Item that has a relationship with a separate Activity Group (see the figure right).
 - The name of the Activity Item will match the name of the Activity Group that provides the detail.



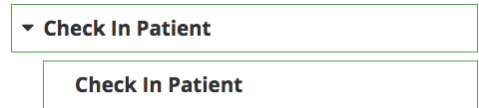
- The Activity Item will be annotated to indicate the type of relationship:
 - Hierarchical relationships should be marked with an "(S)" marker (see figure at right). There are two types of hierarchical relationships:
 - Process to Sub-Process
 - Case to Stage



- Linking relationships should be marked with an "(L)" marker (see figure at right). There are six types of Linking relationships:
 - Process to Process ... through a BPMN Call Activity (aka Linked Process).
 - Process to Case ... through a BPMN Case Task (extension to BPMN).
 - Case to Process ... through a CMMN Process Task.
 - Case to Case ... through a CMMN Case Task.
 - Process to Decision Service ... through a BPMN Business Rule Task.
 - Case to Decision Service ... through a CMMN Decision Task.
- The structure of the Activity Items within an Activity Group provides default semantics for generating the behavior diagrams.
- In general, for BPMN Processes, the order that the activities are listed define the sequence of activities in that Process.

❖ *Note that alternative pathways through a Process cannot be defined with the Activity Group due to the limitations of formatting a list of items.*

- BPMN Tasks are Activity Items that do **not** have any nested sub-items and do not have a linking relationship.
- BPMN Sub-Processes are Activity Items that **do** have nested sub-items (or a defined hierarchical relationship as shown above).
- If it is known that an Activity Item should be a Sub-Process, but the details will be added later, then add a placeholder nested item to show that more detail will be added. The name of the indented placeholder Activity Item could be same as the Sub-Process (see figure at right).
 - In the description of the placeholder, add text to indicate that it is just a placeholder.
- CMMN Tasks are Activity Items that do **not** have any nested sub-items and do not have a linking relationship.
- CMMN Stages are Activity Items that **do** have nested sub-items (or a defined hierarchical relationship as shown above).
- Different types of Activity Items can be flagged with a visual marker to provide a quick mechanism to identify the variety of types captured in the models.



Activity Relationships and the Behavioral Scope Diagram

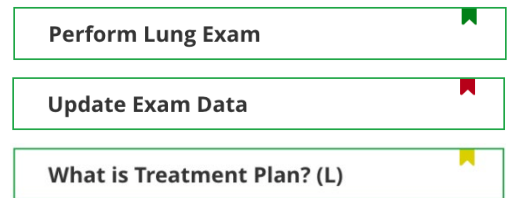
The Knowledge Model Diagram will reflect the Activity Group Linking relationships that are defined in the Library. That is the relationship marker (L) for a Library Activity Item will appear as a connector used to connect to diagram shapes. This will be illustrated in the section on the Knowledge Model Diagram (see [below](#)).

Marking Task Types

The use of colored flags to mark different types of Library Activity Items (Tasks) is only intended to help Shareable Clinical Pathway Producers identify and quickly locate specific types of Tasks.

BPMN has nine types of Tasks and CMMN has five types of Tasks. Not all the types will be flagged. User Tasks will probably be the most common Tasks and do not need to be flagged. It is suggested that only the following activities, which are likely to be used in a Shareable Clinical Pathway, should be flagged:

- BPMN Manual and CMMN User Non-Blocking Tasks. They will have a green flag marker (see figure at right).
- BPMN Business Rule Tasks and CMMN Decision Tasks. They will have a yellow flag marker (see figure at right).
- BPMN Service and Script Tasks. They will have a red flag marker (see figure at right).



❖ *Note that the Field Guide does not specify or recommend a particular scripting language. But using a common, often-used language will increase the ability of a Shareable Clinical Pathway consumer to be able to utilize the language in his/her local environment.*

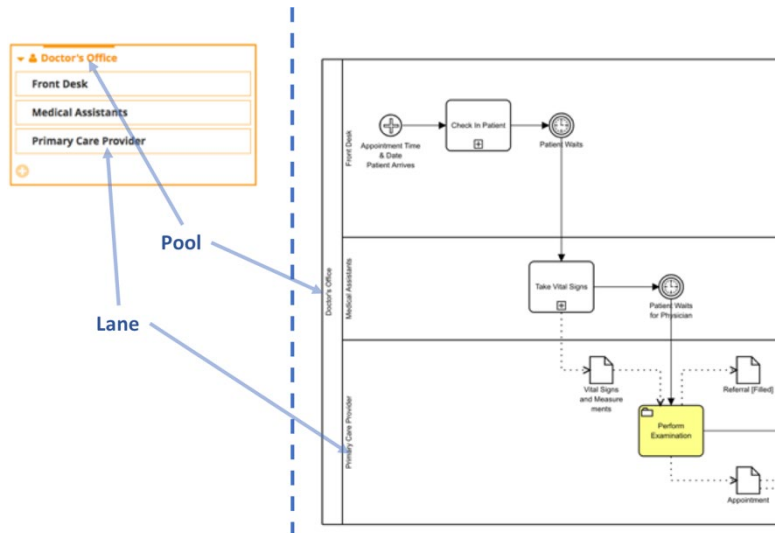
Who – Actors/Performers/Roles

Actors are the "who" of the Clinical Pathway. They represent high-level entities, such as hospitals or labs, and the performers, such as physicians and lab technicians, of the Tasks within the Clinical Pathway.

Since Clinical Pathways often involve interactions between independent participants in the care of a patient, Actor Items (Roles) should be organized in Actor Groups by the Entity/Participant to which they belong.

- In the Hello Patient example, there are two Participants (using BPMN terms) involved in the Clinical Pathway: a Doctor's Office and a Weight Counselors' Office. Thus, there are two Actor Groups in the Library (see figure at right).
- An Actor Group will need to be defined in the Library/5WH Model for each Participant. The Actor Groups will map to BPMN Pools (see figure below).
- The Roles within each Actor Group will be listed as Actor Items and will often map to BPMN Lanes within the Pool (see figure at right).

Who/Actor	
Doctor's Office	Weight Counselor's Office
Front Desk	Weight Counselor
Medical Assistants	
Primary Care Provider	



- Sub-Groups of Actors can be defined within the Actor Group (i.e., they can be nested).
- Actors are related to Activity Groups and Items in four different ways (see below):
 - They are responsible (R) for the activity. This is the most common relationship.
 - They are accountable (A) for the activity.
 - They are consulted (C) during the activity.
 - They are informed (I) about the activity.

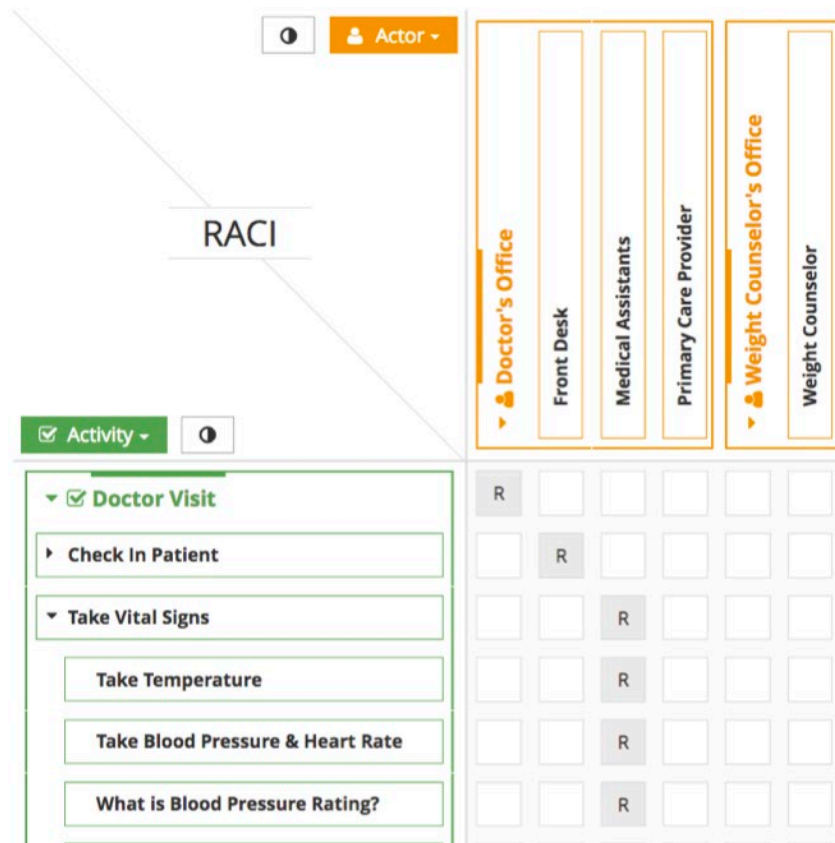


Figure 13 – RACI

What – Artifacts/Data Elements

Artifacts are the "what" aspect of the Clinical Pathway. They represent the data elements that are needed for the Shareable Clinical Pathway. These data elements serve as a "data dictionary" that is the source of data elements in the interconnected BPM+ models of a Shareable Clinical Pathway.

The Artifacts and their details should be limited to the level and scope necessary for the performance and understanding of the Shareable Clinical Pathway. For example, if the pathway is focused on Diabetes, the Artifact elements would be related to supporting that topic, not other topics or all of healthcare. Furthermore, the Artifacts and their details don't have to cover everything about the topic. For example, an Artifact could be defined for the recording of blood pressure. Such an Artifact could be very complex, with more than 50 properties. However, if the pathway only requires the systolic and diastolic measurements, then the blood pressure Artifact will only need those two properties.

By focusing the data elements of a Knowledge Model (Shareable Clinical Pathway) to only that which is needed, the collection of data elements can be referred to as "situational data." Thus, we will refer to the Artifact section of the Library/5WH Model as the "Situational Data Model."

Structuring Data Elements

The way that the Situational Data Model elements are constructed and organized can help in the development and understanding of the BPM+ models for the pathway.

In Healthcare, many of the data elements, particularly a patient health record (PHR), are complicated structures with many levels of detail. See Appendix A – The Information Ecology of Clinical Care. Thus, a data element like the PHR could be the input and output of most activities in Clinical Pathways, even though a small part of the PHR is used during any given activity. For example, a patient's temperature could be taken and the PHR updated. But the Temperature element is many levels down in the structure of the PHR. So, showing the PHR as the output of such an activity does not provide much clarity to the reader of the diagram.

On the other hand, displaying every possible structural element of a large structure as inputs or outputs hides the context of those elements (within the larger structure).

A balanced approach must be taken between having a few large structures displayed in the models or having a lot of individual elements, which are part of the larger structures. The inputs and outputs for the model activities should be informative of the work being done, but do not have to identify the exact structural elements being used.

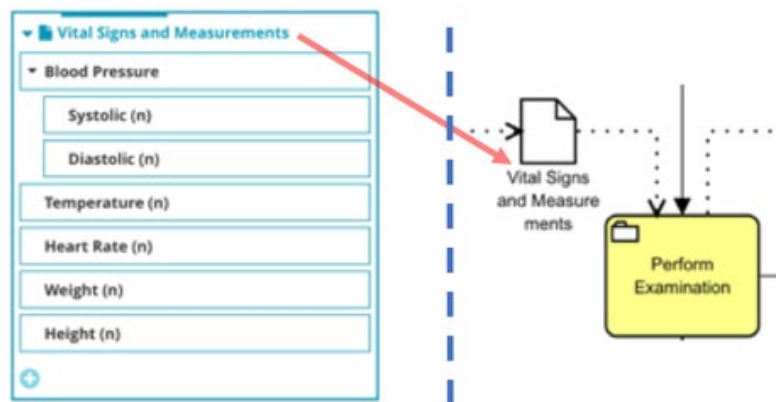
In the Hello Patient example, the update of the patient's temperature is shown to be part of a "Vital Signs and Measurements" data object, which is part of the overall PHR. Likewise, other activities impact an "Exam Data" data object, also part of the overall PHR. By convention, most BPMN Data Objects, CMMN Case File items, and DMN Inputs and Outputs that appear in the Clinical Pathway models should have a separate item defined in the Library/5WH Model as described in this section.

Organizing Data Elements

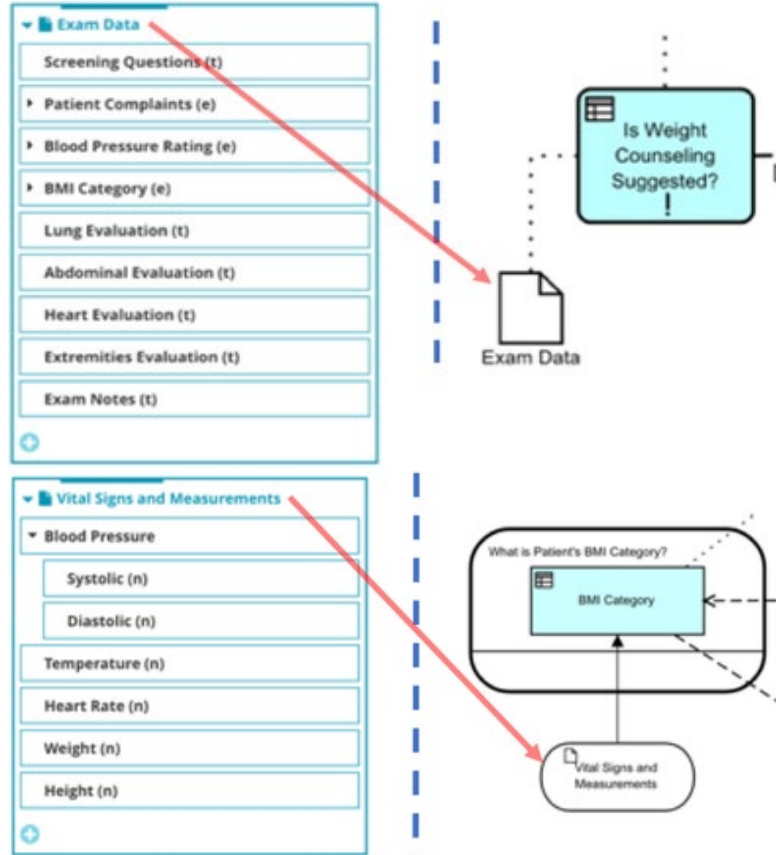
The Situational Data elements in the Library are organized into Data Groups that contain a list of Data Items.

The Data Groups in the Library should match the specific data elements that appear within the BPM+ models within the Shareable Clinical Pathway (exceptions are noted below). For example:

- There should be a Library Data Group for each BPMN Data Object (see figure at right).
 - See the [Including Data Elements in a Process](#) section below for more information about creating BPMN Data Objects.



- There should be a Library Data Group for each CMMN Case File Item (see figure at right).
 - See the [Including Data Elements in a Case](#) section below for more information about creating CMMN Data Objects.



- There should be a Library Data Group for each DMN Data Input (see figure at right).
 - See the [Including Data Elements in a DRD](#) section below for more information about creating DMN Data Inputs.

❖ *Note: As should be apparent, the number and make-up of the Data Groups will be iteratively updated as the BPM+ models of the Shareable Clinical Pathway are developed.*

Data Item Types

If a Producer has knowledge about the types that are used in a data element, then he/she can use markers to show these types in a Situational Data model. It is not required to indicate data element types in the Library. However, Shareable Clinical Pathways developers who would like to see this information in the Library can add the markers.

If a particular modeling tool allows for Library models and provides markers or indications of type information for data elements, then the format of that tool should be used. If the tool doesn't provide type indicators (e.g., if the Library is maintained in an Excel file), then the following styles should be used.

- Data Items that do not contain nested Data Items (i.e., are leaves in the structure) will be assigned a type (e.g., text, Boolean, etc.). After the name of the Data Item (and sometimes a Data Group if it has no items) a textual marker should be added to indicate its type (see figure at right).

Patient Name (t)
- The data type markers should be the following:
 - (b) for Boolean
 - This type should be used sparingly. The enumerated text options of “Yes” and “No” are the preferred method, especially for Gateway conditions.
 - (d) for Date
 - (dt) for Date/Time
 - (e) for enumerated Text
 - The indented Data Items for the enumerated text types (i.e., the enumerated values) do not need to be marked. They are assumed to be text.
 - The exception is (df) for the default item of the enumerated list.
 - (n) for Number
 - (t) for Text
 - (ti) for Time
 - (ym) for Durations of years and months
 - (yn) for a specialized enumerated text item that is specifically two items that are “Yes” or “No.”
- Structures do not need to be marked. They will have nested Data Items in the model, which is enough to show that they are structures.
 - Any Data Group that has Data Items is also a structure (see more details on structures in the next section).
- Data Items that are multi-instance (a collection) should have a "+" appended to their names. In the figure at right, for example, there could be multiple referrals and appointments in a patient's health record.

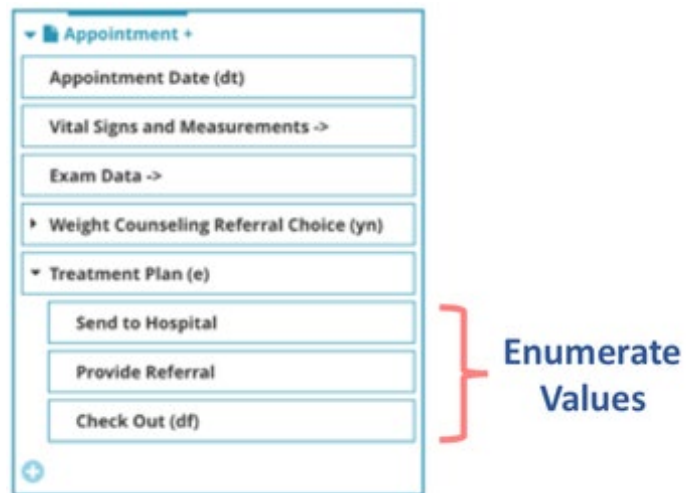
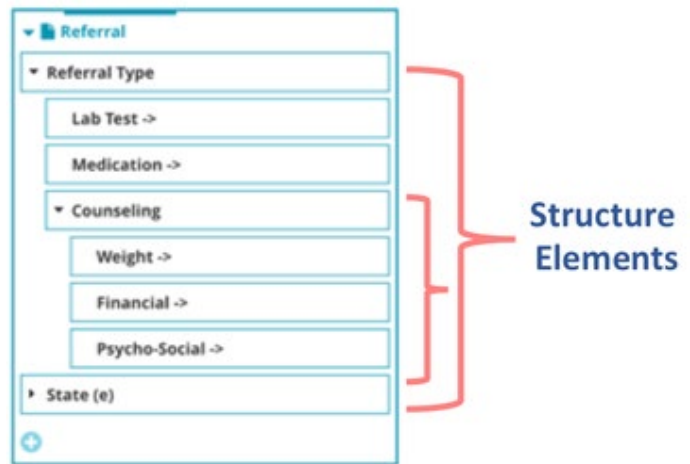
The diagram shows a 'Patient Health Record' structure with four nested data items: 'Patient Name (t)', 'Patient Age (ym)', 'Referral + ->', and 'Appointment + ->'. Red circles are drawn around the '+' characters in 'Referral' and 'Appointment' to indicate that these items are multi-instance.

Data Item Structures:

- Any Data Group that contains Data Items is a structure.
 - A Data Group that does not contain any Data Items can be typed (as shown above).
- Structures can also be created by nesting Data Items within the Data Group.
 - However, not all nesting's will create structures (see below).

Nested Data Items (indented items) are used to:

- Define the structure of the Data Items (see figure at right).
- The enumerated values of text Data Items (see figure at right).
 - The nested Data Items for the enumerated text types (i.e., the enumerated values) do not need to be marked. They are assumed to be text.
 - The exception is (df) for the default item of the enumerated list.

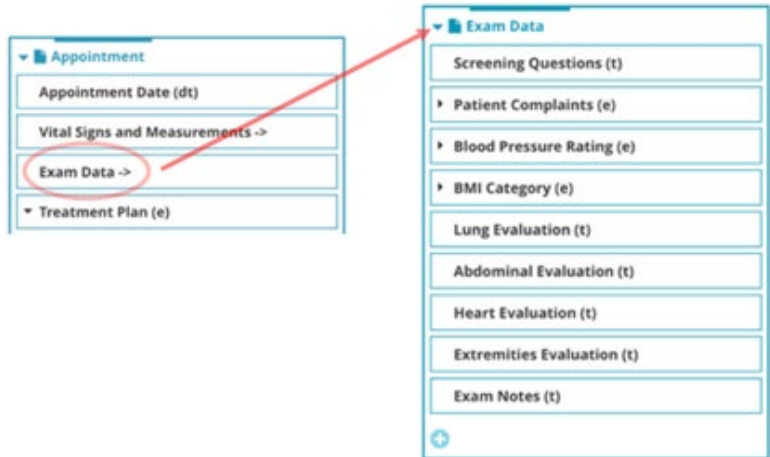


Specifying Data Groups Relationships

As described above, the Data Groups represent data elements that are being used in the Shareable Clinical Pathway's Processes, Cases, and Decision Services. However, a Data Group may be part of a larger structure. The relationships among Data Groups will be similar as those among Activity Groups (as shown above).

Linking one Data Group as a part of another Data Group is done as follows:

- Within the parent Data Group there will be a Data Item that has the same name as the child Data Group.
- The Data Item in the parent Data Group will have a "->" appended to its name. This indicates that the details of that item are stored within the other Data Group of the same name (see figure at right).
 - But, the combination of the two Data Groups represents a single, complex data element.



Relationships Among Data and Activities

Data Groups and Items can be set as inputs, outputs, or both for Activities (see below, Figure 14).

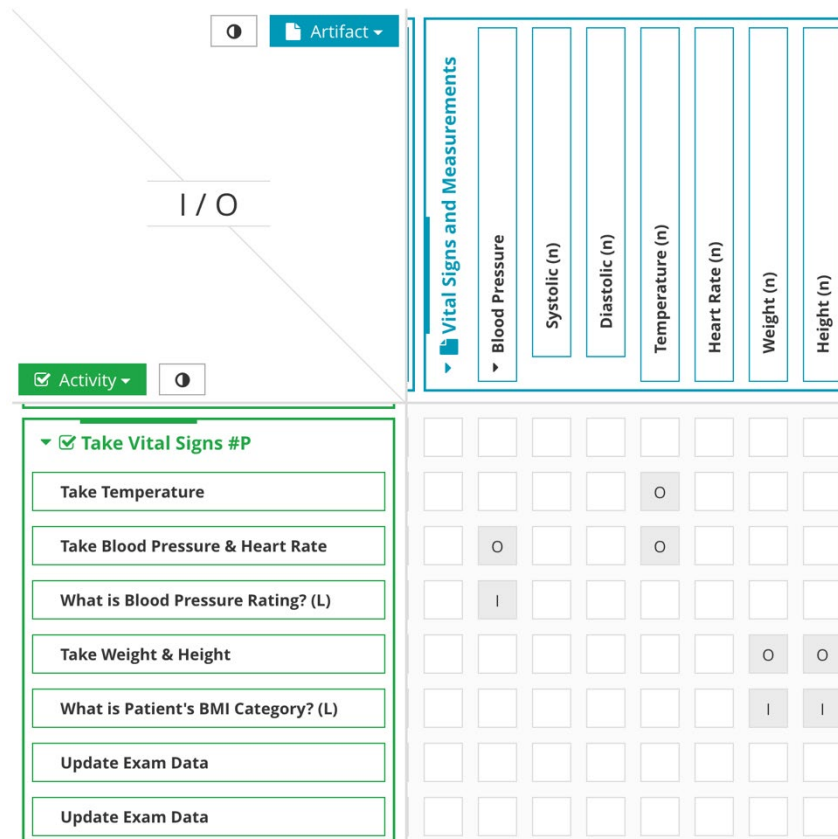
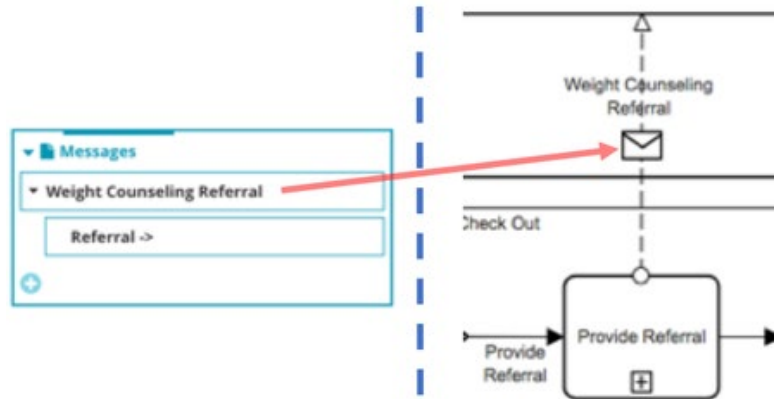


Figure 14 – Input, Outputs & Both

Specialized Data Groups

Some data elements are captured together under specific, named Data Groups and are the exceptions to the conventions described above. These exceptions are:

- DMN Decision Service Outputs. The Situational Data Model Data Group will be named "Decision Outputs."
 - This is described in more detail in the section [Decision-Related Elements](#) below.
- BPMN Messages. The Data Group will be named "Messages."
 - The Data Items within this Data Group will be the individual Messages that appear in the Collaborations of the Clinical Pathway.
 - The content of the Message is shown as a sub-Data Item, and this item should have a corresponding Data Element within the Situational Data Model; thus, it will have a "->" appended to its name (see figure at right).



When - Events

Events are things that happen during the Clinical Pathway and they usually will trigger the performance of a Process or an Activity.

The event elements in the Library are organized into Event Groups that contain a list of Event Items.

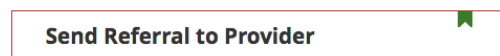
- Events that are identified in the Library/5WH Model are related to specific BPMN Processes or CMMN Cases. Therefore, the label of the Event Group will match name of the corresponding Activity Group (see below).

When/Event	
Doctor Visit	Perform Examination
Appointment Time & Date	2 Years since last Physical
Patient Arrives	
Patient Waits	
Patient Waits for Doctor	
Send Referral to Provider	
Leave Office	
Patient Enters Hospital	
Exam Recording Completed	

Figure 15 – When / Event

Different types of Events can be flagged with a visual marker to provide a quick mechanism to identify the variety of types captured in the models. BPMN has 12 types of Events and CMMN has three types of Events. Not all the types will be flagged. Only the following Events will be flagged:

- BPMN Message Events. They will have a green flag marker (see figure at right).



- BPMN Signal Events. They will have a yellow flag marker (see figure at right).
- BPMN and CMMN Timer Events. They will have a red flag marker (see figure at right).

Enter Hospital 

Patient Waits for Doctor 

The Event items in the Library/5WH Model represent all categories of process model events:

- BPMN Start Events, Intermediate Events, End Events for the events that are related to Activity Groups that represent a BPMN Process. The relationship of the Event to the Activity Items will determine the category of Event.
- Start Events will have only a trigger relationship to an Activity item.
- Intermediate Events will have a trigger *and* a result relationship to Activity items.
- End Event will have only a result relationship to an Activity item.
- CMMN Event Listeners for Activity Groups that represent a CMMN Case.
- These Event items will only have a trigger relationship to an Activity item (see [Figure 16](#) below).

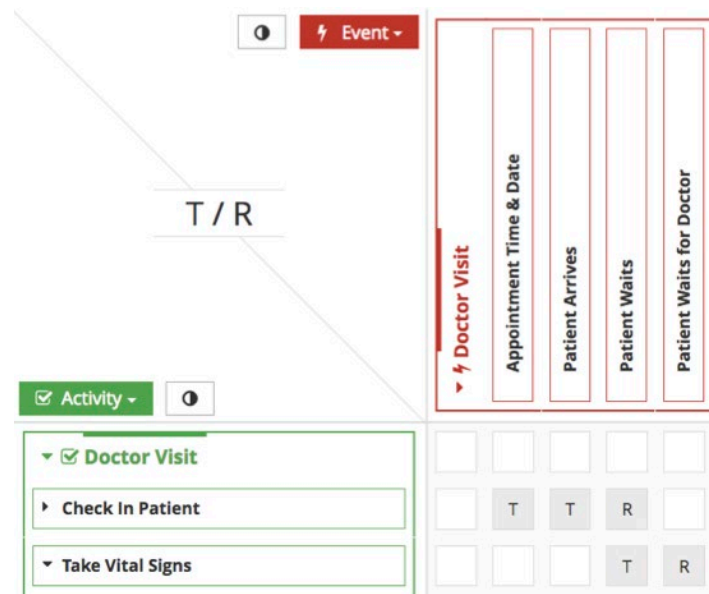


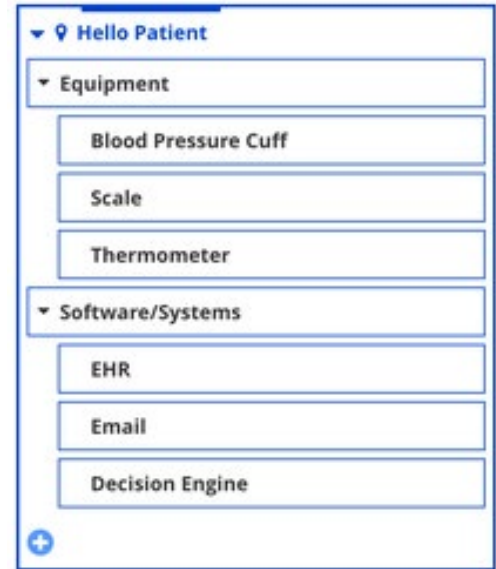
Figure 16 – Trigger & Results

Where – Systems

Systems represent all non-human resources that are utilized for BPMN Tasks.

The systems elements in the Library are organized into System Groups that contain a list of System Items.

- The System items can be organized into categories, such as Equipment or Software, as appropriate for the Clinical Pathway.
- The actual system resources will be System Items for the appropriate System Group (see figure at right).



A relationship is created among the system resources and the appropriate Activity Items in the Library/5WH Model (as well as any BPMN diagrams).

❖ *Note that system resources can't be assigned to CMMN Tasks.*

Why – Goals

Goals are defined for the Clinical Pathway as a whole. Thus, the label for the Goal element in the Library/5WH Model should be the same as the name for the Clinical Pathway (see figure at right).

The goal elements in the Library are organized into Goal Groups that contain a list of Goal Items.

Why/Goal
Hello Patient
Complete Examination of Patient
Address Hypertension
Address Need for Weight Counseling

The goals usually represent specific milestones that should be achieved during the course of the Clinical Pathway. Goals are part of the metadata that should be captured about the Knowledge Model.

Decision Related Elements

A *Decision* within a Clinical Pathway involves multiple elements across the BPM+ models. These elements related to *Decisions* will be listed in the Library/5WH Model in multiple places:

Activities

- Business Rule Tasks in BPMN Processes and Decision Tasks in CMMN Cases will be listed in the Library as Activity Items within the appropriate Activity Groups.
 - These Tasks will link to DMN Decision Services (see the section Modeling Styles for Business Rule Tasks below).
- These Tasks should be named in in the form of a question: e.g., "What is Treatment Plan?" (see figure at right).
 - To highlight these activities from other activities in the Library, they can be marked with a yellow flag marker.



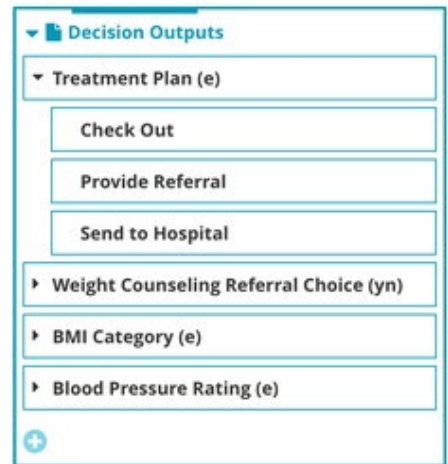
See the [Modeling Styles for Business Rule Tasks](#) section below to see how these types of activities are used in a BPMN Process and see the [Modeling Styles for Decision Tasks](#) section below to see how these types of activities are used in a CMMN Case.

Artifacts/Data

The situation is more complex since DMN Decision elements represent both the computation logic for the decision and the data output of that computation. The computation logic is utilized through the link between the Process Task and DMN Decision.

To represent the data output aspect of the DMN Decision, they will be represented in the Library/5WH Model as items within a specialized Data element.

- The label of the Data Group will be named "Decision Outputs."
- The individual DMN Decision Outputs will be listed within the "Decision" Data Group (see figure at right).



Each of the items in the Decisions Artifact will be represented as Decision elements (see [Figure 17](#) below).

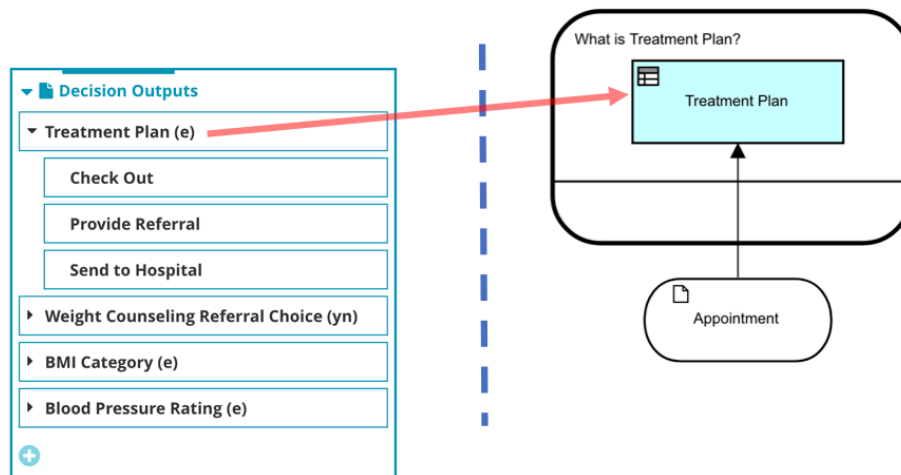


Figure 17 – Decision Artifacts

Each of the items in the Decisions Artifact will be represented as BPMN Data Objects, CMMN Case File Items, or both. These data objects are the outputs of the Tasks that links to the DMN Decision object. They are **not** part of a larger structure but are stand-alone data elements (see [Figure 18](#) below).

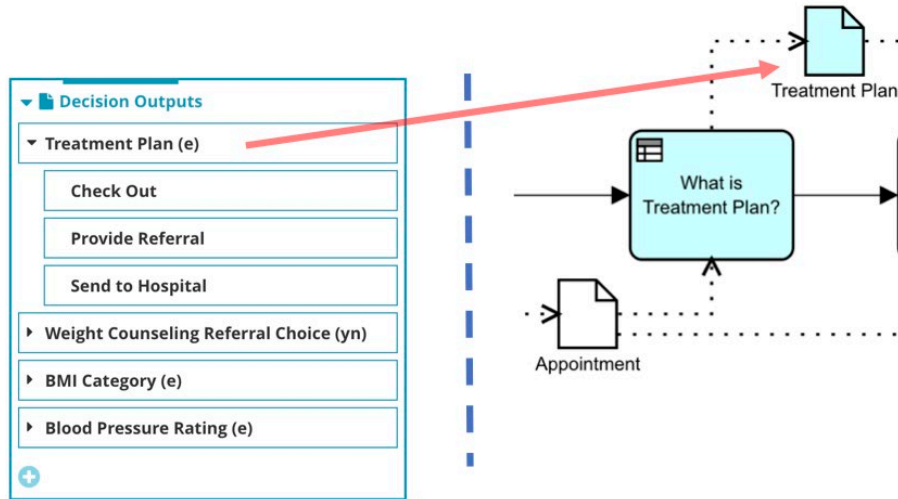
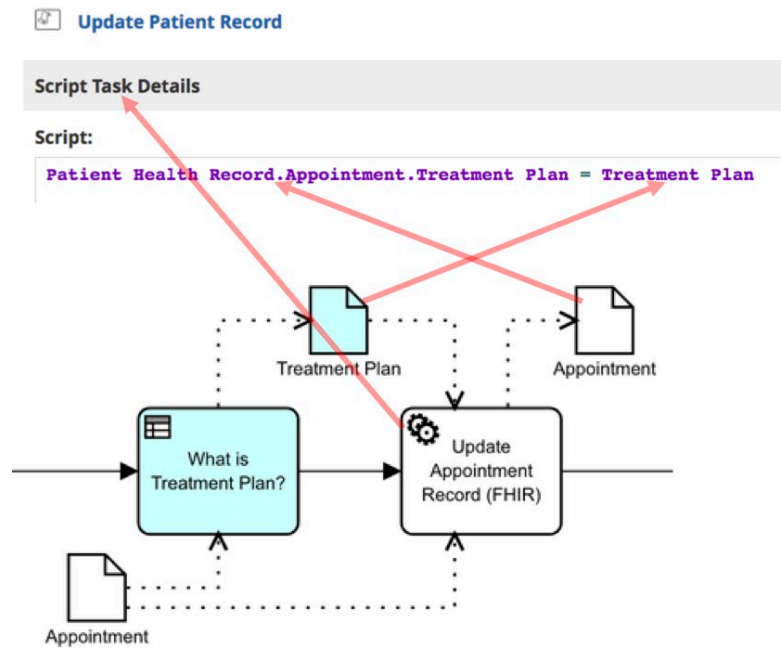


Figure 18 – Decision Output Data Object

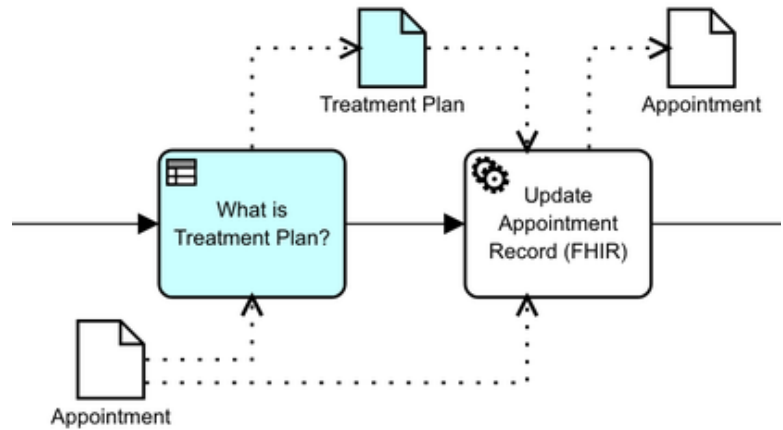
A separate BPMN (or CMMN) activity will be needed to transfer the data from a Decision to another data element (such as the PHR).

For example, this could be done through a BPMN Script Task that performs the assignment function to copy the data (see figure at right).



Or the update could be done through a Service Task.

- The Service Task could call a FHIR Service, for example see figure at right.



The inputs for a DMN Decision will be a separate Library/5WH Model Artifact element. (An example of this is shown in the previous sub-section.)

- ❖ Note that all of the DMN Decision Inputs will have a corresponding BPMN Data Object or CMMN Case File item as inputs into the Tasks that are linked to the DMN Decision.

Services

A special Service Groups will be named "Decisions Services" (see figure at right).

- All of the DMN Decision Service models will be listed as Service Items within this Service Group.

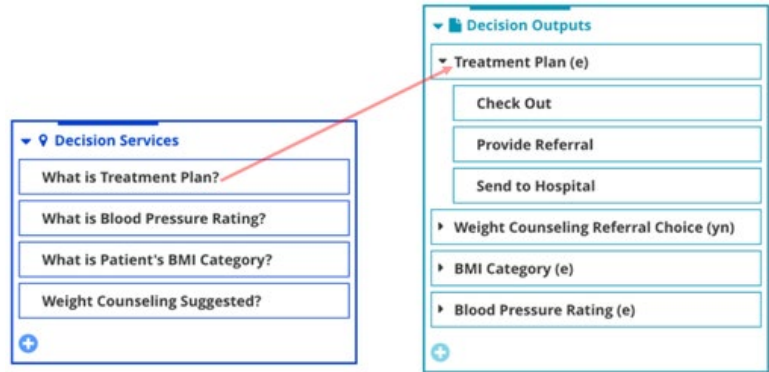


Each of the Decision Services will have a corresponding Activity Item within an Activity Group (that has the same name).

- The Activity Item will be marked as having a Linking Relationship (to the Decision Service). See figure at right.



- Each of the Decision Services will have one or more Data Items from the Decision Outputs Data Group that serves as the output of that Decision Service (see figure at right).



Modeling Elements that are not in the Library

Not all Process, Case, or Decision model elements will appear in the Library. Here is a list of some of the significant elements that do not appear in the Library (this is not an exhaustive list):

BPMN Process Gateways

Gateways define the branching points of the process and will be determined during the development of a Process. But there is no corresponding element in the Library.

- ❖ *Note that there is often a Business Rule Task that provides the data that will be used in an Exclusive or Inclusive Gateway. It is a recommended style to match the name of a Business Rule Task and the Gateway that controls the flow based on linked Decision Service (See Using Business Rule Tasks, below).*

Knowledge Model Diagram

This document introduces a new diagram construct: *A Knowledge Model Diagram*⁷. This diagram was created to provide a visual representation of the breadth and relationships of the models that make up a Shareable Clinical Pathway (a type of Knowledge Model). Thus, the Knowledge Model Diagram is a unique, high-level view of a Shareable Clinical Pathway depicting its scope (size and complexity) through a graphical representation of each individual BPM+ model that is part of the pathway.

The purpose of the diagram is to show all the Clinical Pathway's behavioral and supporting model elements and their relationships.

- The Knowledge Model Diagram elements are:
 - BPMN Processes;
 - BPMN Collaborations and Choreographies;
 - CMMN Case Models;
 - DMN Decision Services;
 - Undefined Activities;
 - Other Knowledge Models (other Shareable Clinical Pathways); and
 - Situational Data Model (in the Library/5WH)
- The relationships are shown through the Link Connectors representing:
 - The relationship between a Process and a Case or a Case and a Process, etc.
- A grouping object is used to identify diagram elements that are related to each other (see [Figure 19](#) below).
 - For example, there could be a group of elements for activities done within a Doctor's Office and another group for activities done outside the office.

⁷ In the Field Guide V1.0, this diagram was referred to as the Architectural Scope Diagram.

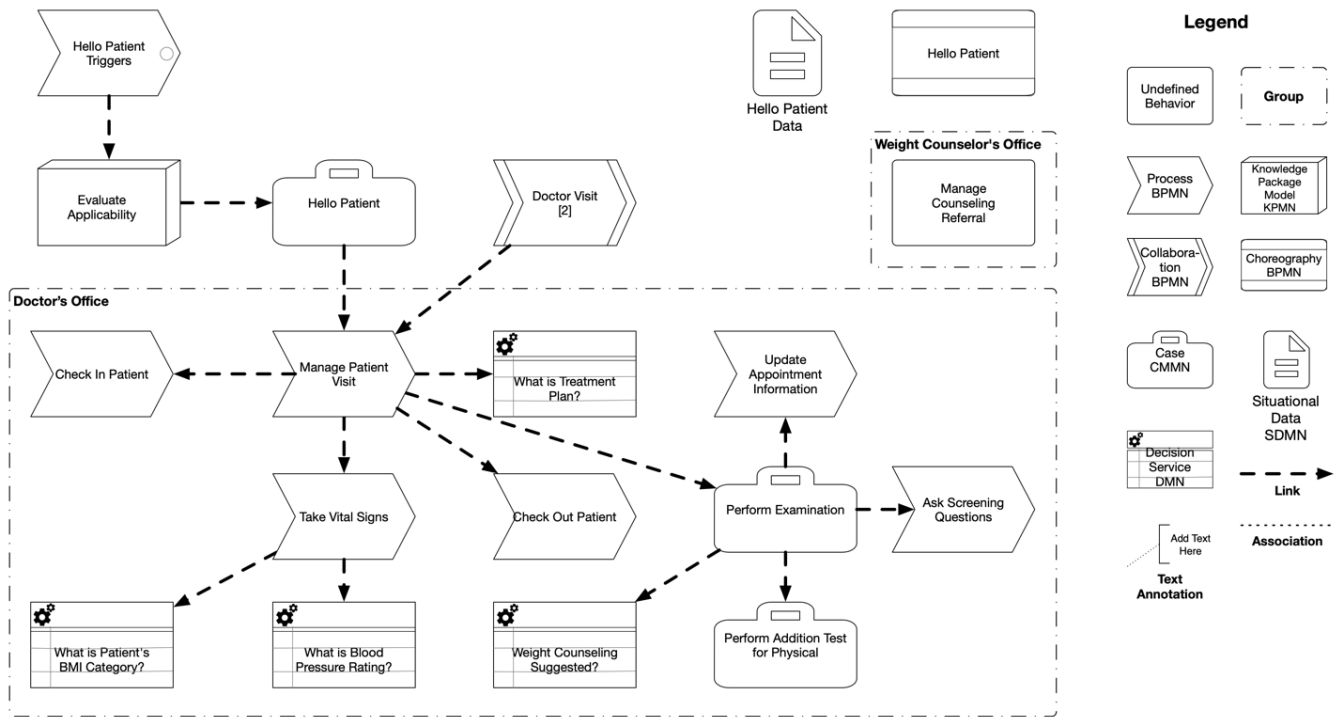


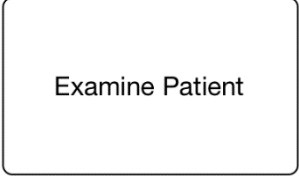
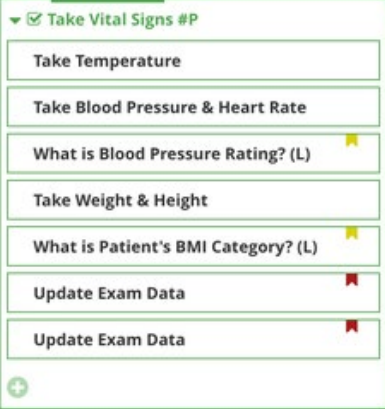

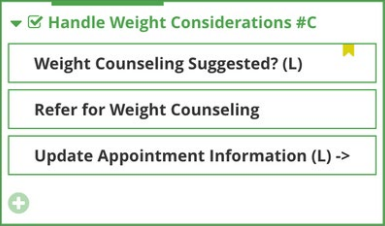

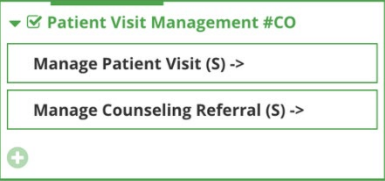



Figure 19 – Knowledge Model Diagram for the "Hello Patient" Example – with Legend


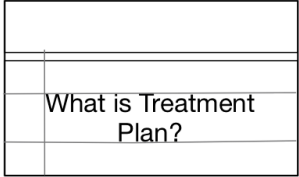



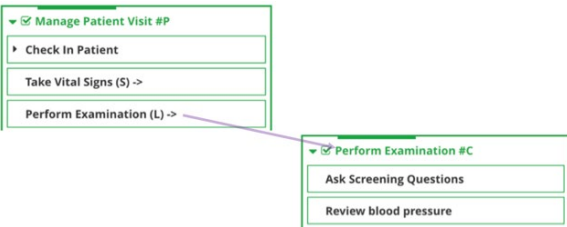
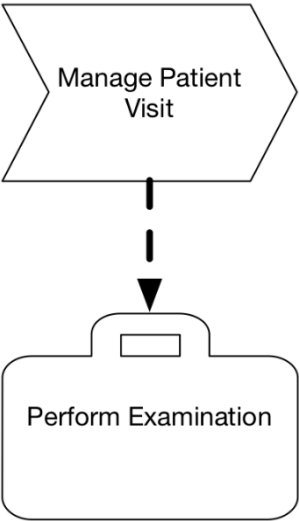
The diagram may not be required for all clinical pathway model sets.

- If the clinical pathway contains seven or more of the diagrams modeling elements, then a Knowledge Model Diagram should be created and maintained.
 - See the Appendix for a list and description of the diagram elements.
 - ❖ Note there is no formal documentation or tooling for this Diagram at this time.

Library Activity Relationships to Knowledge Model Elements

The following table illustrates the relationships among the Library/5WH Model Activity elements and the elements on the Knowledge Model Diagrams.

Element Type	Library Element(s)	Knowledge Model Representation
Undefined Activity		
BPMN Process/Sub-Process		
CMMN Case/Stage		
BPMN Collaboration		
BPMN Choreography		

DMN Decision Services		
Model Scopes (other Shareable Clinical Pathways)		
Library (Situational Data)	Hello Patient Artifacts	 <p>Hello Patient Data</p>
Linking Relationship		

4.3.2. BPMN Process Models

General Modeling Styles

These are some general considerations for creating readable BPMN Process models:

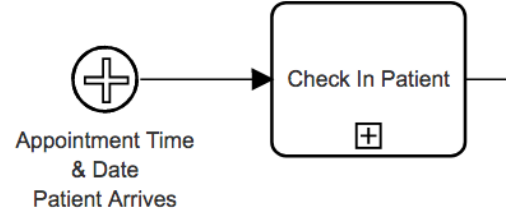
- The flow of the Process should generally move from left to right.
- Also try to avoid zig-zag flow unless a sequence of flow stretches more than 10 activities.
- Happy or critical path should be obvious as the path that is shown on the left-to-right path, relatively unbroken.
- Lower probability paths and exception paths should be shown as deviating from the main path.

Modeling Styles for Start and End Events

The following best practices will add additional verbosity to the diagrams but will add clarity for the behavior and consistency across modeling projects. This will especially benefit the readers of the models who are not experienced Producers.

Always include a Start Event for a Process level (see figure at right).

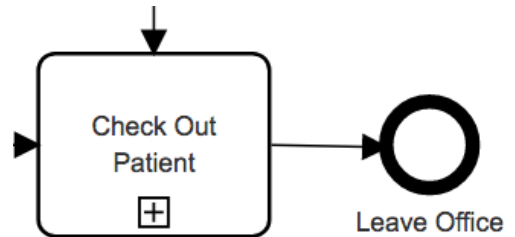
- This Event should be named.



Always include an End Event for each path of a Process level (see figure at right).

- This Event should be named and, when appropriate, represent an "end state."

Exception: If the Producer wants to show a few parallel activities without the overhead of the starting and ending Parallel Gateways and all the necessary Sequence Flows, then a "Parallel Box" can be used. This is a simple Sub-Process where there is no Start or End Events, or no Gateways or Sequence Flows. There would only be a few, disconnected activities. The behavior is the same as using matching Parallel Gateways with the activities connected between, but without the visual clutter.



Modeling Styles for Process Activities

Task Types

The majority will be User Tasks but also be sure to document the Manual, Service, Business Rule, Script, and any type that is relevant for the Process (see [Figure 20](#) below).

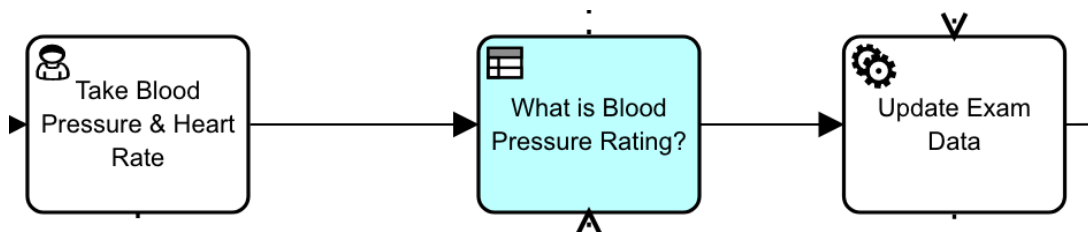


Figure 20 – Using Activities

None (Abstract) Tasks are used only in the early stages of the modeling and are placeholders for the detailed Task information.

Color Coding Tasks

There is no specific use of colors defined in the BPMN specification. It is the prerogative of Producers or modeling-tool vendors to make use of colors if they want to enhance the information presented in the diagrams. For the method and style being proposed in the Field Guide, we recommend that some color coding be added to the Shareable Clinical Pathway diagrams to highlight specific characteristics of Tasks. These recommendations are detailed below.

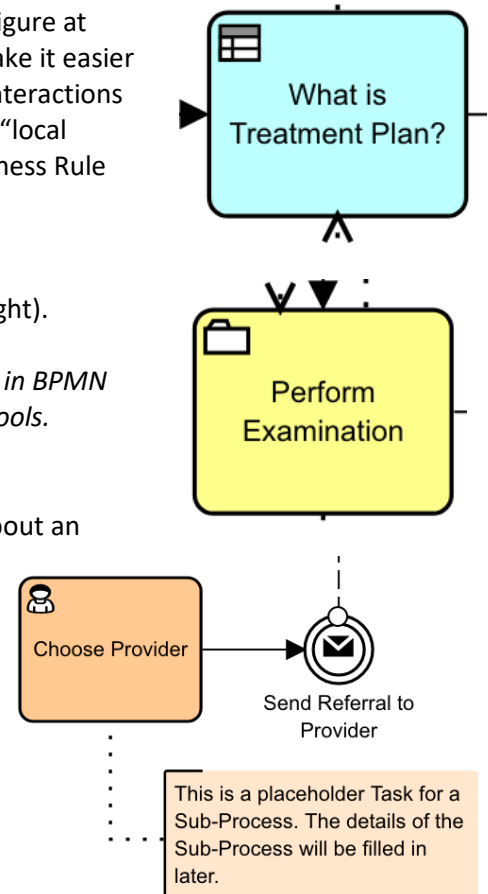
Light Blue:

- Use this color to mark that the Task is a Business Rules Task (see figure at right). The marker identifies the type of Task, but the color will make it easier to locate these Tasks. This is important since there can be many interactions between BPMN and DMN. This color is also the same color as the “local variable” color for those Data Objects that are output from a Business Rule Task (see recommendation below).

Light Yellow:

- Use this color to mark that the Task is a Case Task (see figure at right).
 - ❖ *Note that the Case Task is actually an extension in BPMN that is commonly available in BPMN modeling tools.*

- Light Orange:
 - Use this color to indicate that more information is required about an object (see figure at right). This will mainly be used during the development of a Shareable Clinical Pathway. A completed Clinical Pathway should not have light orange elements unless there are questions that pertain to the localization of the element.
 - Annotations can also be added to help describe the situation. And these types of Annotations can be color-coded as well.



Sub Processes

- The use of expanded or collapsed Sub-Processes is a choice of the Clinical Pathway Producer.
 - Collapsed Sub-Processes were used in the Hello Patient example.

Placeholder Sub-Processes

Some Sub-Processes will initially have placeholder tasks, which were added just to mark that more detail will be added later. In this case, the name of the Sub-Process and the placeholder Task within the Sub-Process will be the same. Also, a Text Annotation should be attached to the Task describing the situation of the Task as a placeholder (see [Figure 21](#) below).

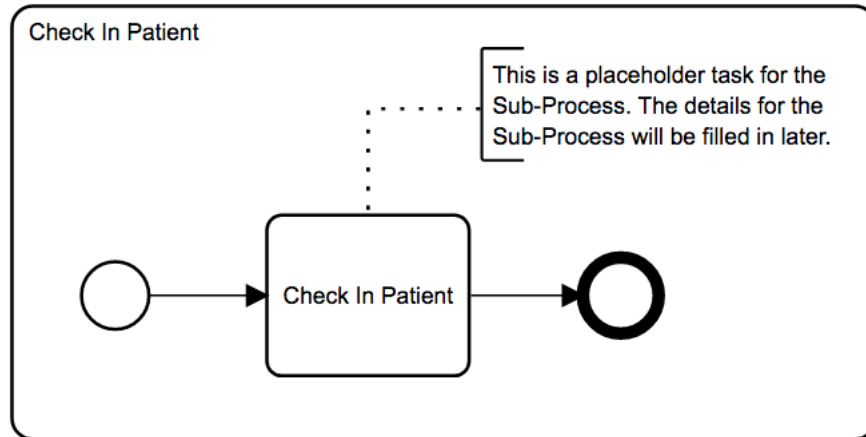
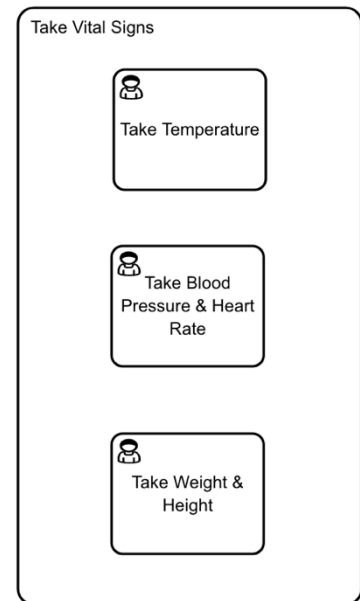


Figure 21- Placeholder Sub-Process

Unstructured Sub-Processes

If there is a small set of parallel activities in a Sub-Process, then do not show the Start Event, End Event, Parallel Gateways, and Sequence Flows (see figure at right).

- ❖ *Note this layout of the Tasks is equivalent to using a Start Event, then a Parallel Gateway connecting to the three Tasks, then synchronizing the three flows with a merging Parallel Gateway, then an End Event. This reduces a lot of clutter and provides the same behavior.*

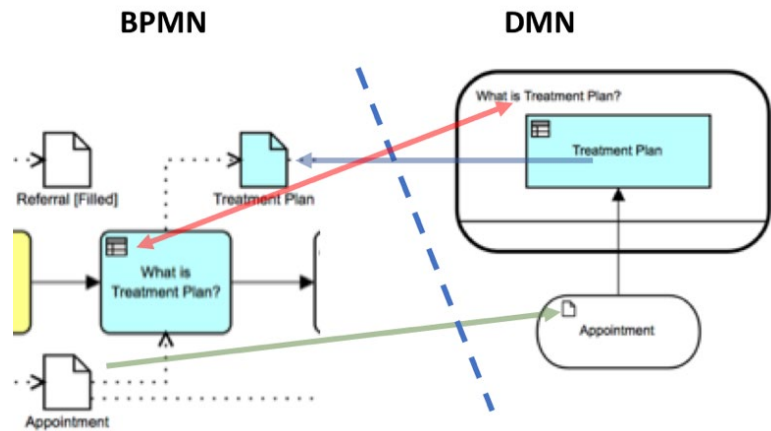


Modeling Styles for Business Rule Tasks

In a BPMN Process, the Business Rule Task is programmatically linked to a DMN Decision Service. The Business Rule Task will invoke the Decision Service, which will return the output of that service to the Process.

The relationships between BPMN and DMN are these:

- The name of the BPMN Business Rule Task, which should be in the form of a question, should match the name of the DMN Decision Service that is linked to the Business Rule Task (see “What is Treatment Plan?” in the figure at right).
 - The Business Rule Task will be color-coded light blue.
- The Input Data Object(s) to the Business Rule Task in the should match exactly the Input(s) – name and structure – for the DMN Decision Service (see “Appointment” in the figure at right).
 - The structure of the DMN Decision Object and Process Data Object usually will be a simple type, often enumerated text. These objects will be color-coded light blue.



These relationships are similar between CMMN Decision Tasks and DMN Decisions (see the section [Modeling Styles for Decision Tasks](#) below).

Manual vs. User Tasks

It is not always obvious whether a Manual Task or a User Task should be used in a BPMN Process. For the most part, a Manual Task is a type of Task that cannot be automated: It is outside the domain of a workflow engine (e.g., the Task will not show up on a user’s task list for the user to accept and perform). An example in the healthcare domain would be the physical transfer of a patient from one room to another. The Task to move the patient can be modeled in the Clinical Pathway but it would not be tracked by a workflow engine.

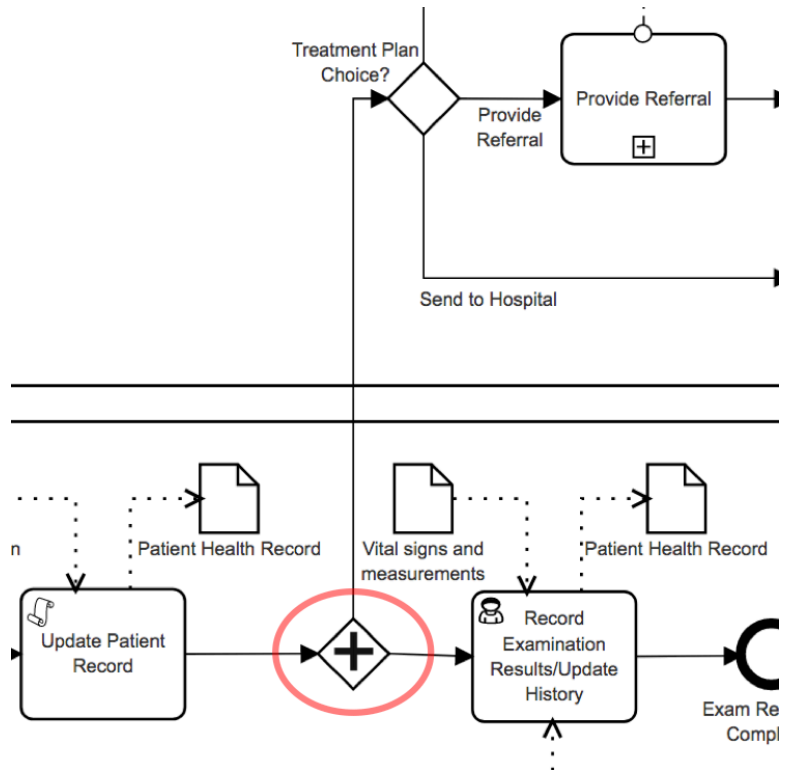
Our recommendations for the choice of task type are:

- User Tasks should have a preference.
- If a Task is fundamentally manual, then use the Manual Task.
- If a Task may be Manual or User, depending on the technology of a particular healthcare facility, then a Non-Task should be used.
- The localization of the Task during the Consumer phase of the Shareable Clinical Pathway will adjust the Task as Manual or User as appropriate for the technology of the target facility.

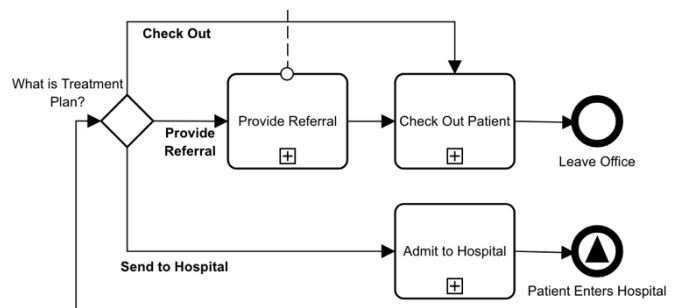
Modeling Styles for Gateways

- Use matching splitting and merging Gateways when possible.

- BPMN does not require splitting Parallel Gateways except for a few situations. However, the use of a splitting Parallel Gateway will make the behavior of the Process easier to understand (see figure at right).

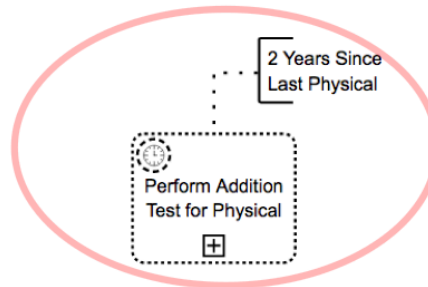
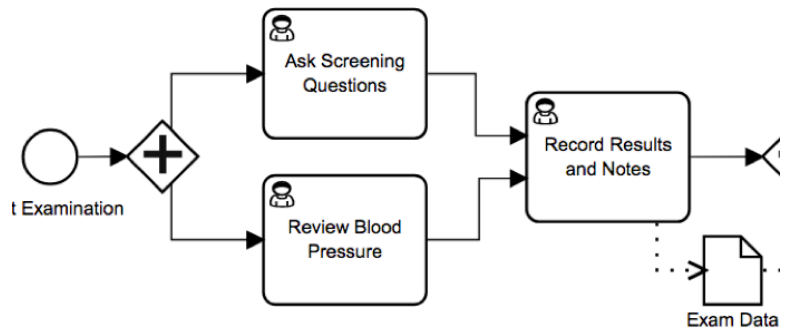


- Use matching splitting and merging Exclusive Gateways.
- Use matching splitting and merging Inclusive Gateways.
- Event Gateways should be merged with Exclusive Gateways.
- Don't use matching Gateways in situations that would make the diagram unnecessarily complex (e.g., when the paths are in separate Lanes). Or when you have distinct outcomes across the paths (see figure at right).



Modeling Styles for Event Sub Processes

- If there is a Process that has a well-defined structure (e.g., it should be a Process rather than a Case), but it has a couple of activities that are not connected to the base structure, then Event Sub-Processes should be used vs. converting the model to a Case diagram just to handle a couple of disconnected activities (see figure at right).



Modeling Styles for Sequence Flows

- Outgoing Sequence Flows for an Activity should not be Conditional.
- Gateways should be used for conditional branching.

Including Data Elements in a Process

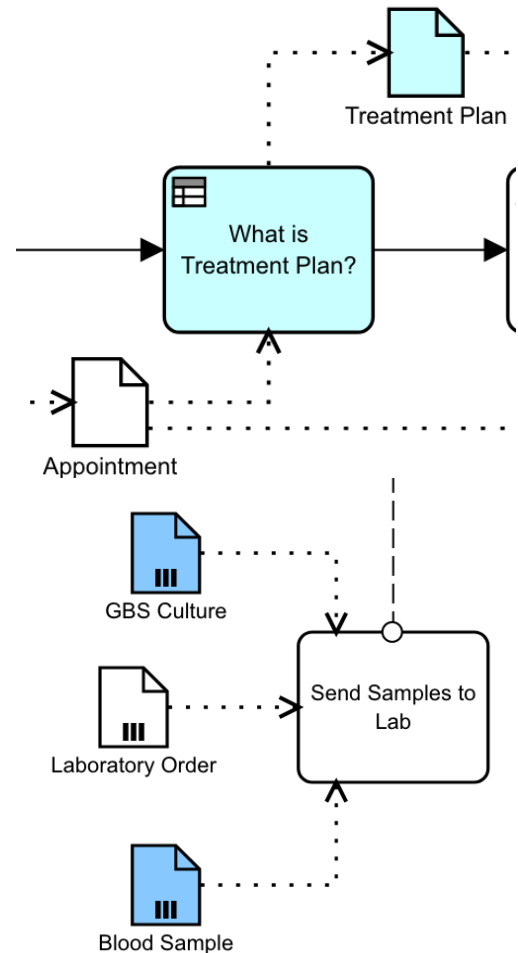
- Data Objects are used to represent the information that is input to and output from the activities in a Process.
- A Data Object (name and type) should have a matching entry in the Library/5WH Model.
- This is also true for Data Inputs and Data Outputs.
- Local Variables (e.g., loop counters) do not require a matching entry in the Library/5WH Model.

Color Coding Data Objects

There is no specific use of colors defined in the BPMN specification. It is the prerogative of Producers or modeling-tool vendors to make use of colors if they want to enhance the information presented in the diagrams. For the method and style being proposed in the Field Guide, we recommend that some color coding be added to the Shareable Clinical Pathway diagrams to highlight specific characteristics of Data Objects. These recommendations are detailed below.

Light Blue:

- Use this color to indicate that the Data Object matches the Data Output of a DMN Decision (see figure at right). In this sense, it is a “local variable” and any information the Data Object holds would have to be transferred to a more permanent Data Object part of the Patient’s record (e.g., through a Service or User Task).
 - The use of this color coding will help the reader of the diagram to distinguish between Data Objects relevant to the patient (no color) and Data Objects relevant to the Process (light blue; e.g., as in the figure at right).
- Darker Blue:
 - Use this color to indicate that the Data Object is a physical item (such as a blood sample; see figure at right).



Utilizing Services

A Service Task is used to provide a position in a Process where a service can be called, and the product of that service applied to Process data.

The inputs to the Task (Data Objects) are mapped to the inputs of the Service. The outputs of the Service are mapped to the outputs of the Task.

4.3.3. CMMN Case Models

CMMN Case models can use the breadth of CMMN capabilities. However, there are few specific method and style guidelines that are necessary when modeling Clinical Pathways. The sections below define these best practices.

Modeling Styles for Case Activities

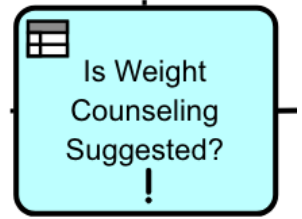
Color Coding Tasks

There is no specific use of colors defined in the CMMN specification. It is the prerogative of Producers or modeling-tool vendors to make use of colors if they want to enhance the information presented in the diagrams. For the method and style being proposed in the Field Guide, we recommend that some color coding be added to

the Shareable Clinical Pathway diagrams to highlight specific characteristics of Tasks. Our recommendations are detailed below.

Light Blue:

- Use this color to mark that the Task is a Decision Task (see figure at right). The marker identifies the type of Task but the color will make it easier to locate these Tasks. This is important since there can be many interactions between CMMN and DMN. This color is also the same color as the “local variable” color for those Case File Items that are updated by a Decision Task.



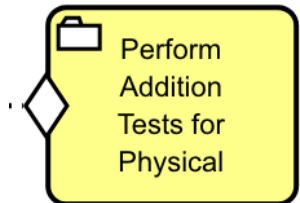
Light Yellow:

- Use this color to mark that the Task is a Process Task (see figure at right). The marker identifies the type of Task but the color will make it easier to locate these Tasks. This is important since there can be many interactions between BPMN and CMMN.



Light Yellow:

- Also use this color to mark that the Task is a Case Task (see figure at right). The marker identifies the type of Task, but the color will make it easier to locate these Tasks. This is important since there can be many cross-CMMN model interactions.

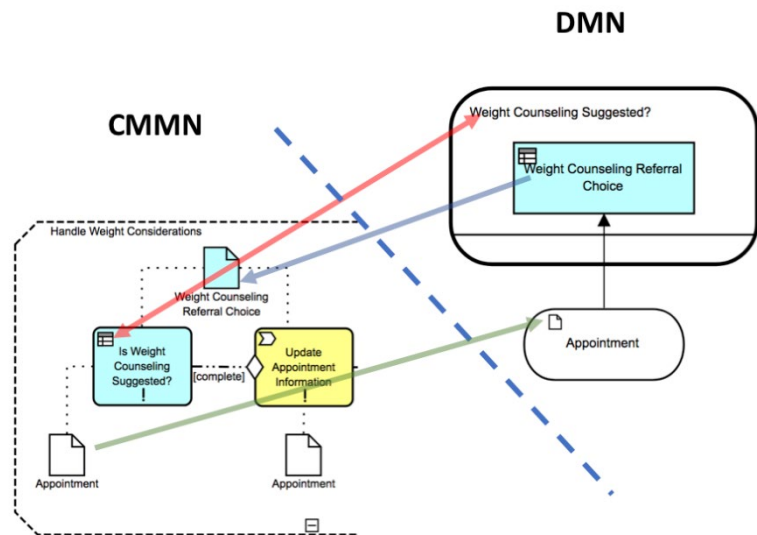


Modeling Styles for Decision Tasks

In a CMMN Case, a Decision Task will be programmatically linked to a DMN Decision Service. The Decision Task will invoke the Decision Service, which will return the output of that service to the Case.

The relationships between CMMN and DMN are these:

- The name of the CMMN Decision Task, which should be in the form of a question, should match the name of the DMN Decision Service (see “Weight Counseling Suggested?” in figure at right).
 - The Decision Task will be color-coded light blue.
- The Case File Item(s) that will provide data for the Decision Task in the CMMN Case Model should match exactly the Input(s) – name and structure – to the DMN Decision Service (see “Appointment” in figure at right).



❖ Note that the input/output flow of Case File Items with Case Tasks does not need to be notated in the same way as occurs in BPMN. Instead, the Field Guide method and style uses association connectors to help the reader visualize the relationships (see next section).

- The Case File Item that will receive data from the Decision Task in the CMMN Case Model should match exactly the output Decision Object – name and structure – within the DMN Decision Service (see “Appointment” in figure at right).
 - The structure of the DMN Decision Object and Case File Item usually will be a simple type, often Enumerated Text. These objects will be color-coded light blue.

Including Data Elements in a case

A Case File item (name and type) should have a matching entry in the Library/5WH Model.

- Use an Association connector (directed) to show how a Case File item is the input or output of an activity (see Figure 22 – Input and Output Data Objects, below).
 - ❖ Note that the Association is not necessary for Case model definition. It is a recommended style used in Shareable Clinical Pathways to provide clarity about activity requirements.

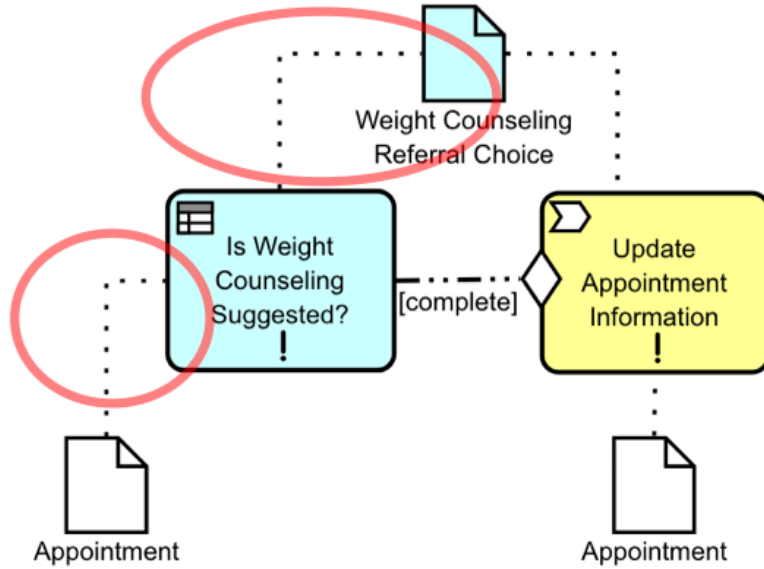


Figure 22 – Input and Output Data Objects

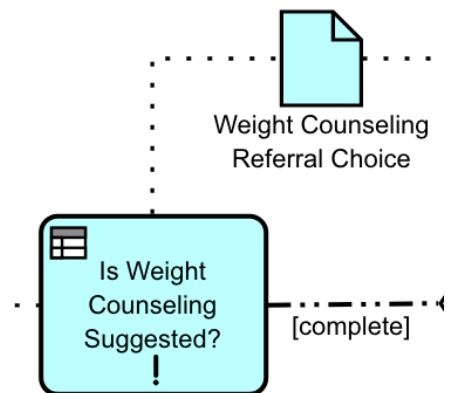
Color Coding Case File Items

There is no specific use of colors defined in the CMMN specification. It is the prerogative of Producers or modeling-tool vendors to make use of colors if they want to enhance the information presented in the diagrams. For the method and style being proposed in the Field Guide, we recommend that some color coding be added to the Shareable Clinical Pathway diagrams to highlight specific characteristics of Case File Items. Our recommendations are detailed below.

Light Blue:

- Use this color to indicate that the Case File Items matches the Data Output of a DMN Decision Service (see figure at right). In this sense, it is a “local variable” and any information the Case File holds would have to be transferred to a more permanent Data Object part of the Patient’s record.

The use of this color coding will help the reader of the diagram to distinguish between Case File Items relevant to the patient (no color) vs. Case File Items relevant to the Process (light blue; e.g., as in the above example).



Utilizing Services

Services are not explicitly modeled in CMMN.

If a service needs to be executed during the course of a Case, then include a Process Task.

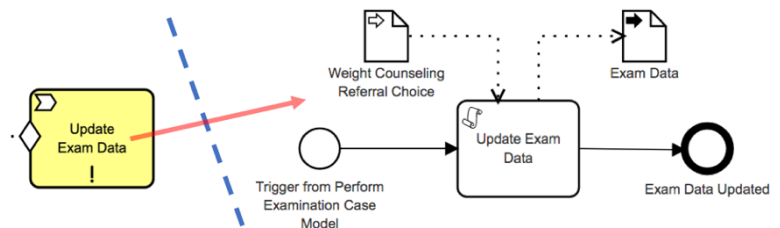
The referenced Process can contain a Service Task that will execute the service when triggered by the Case.

Handling Scripts

Scripts are not explicitly modeled in CMMN.

- If a script needs to be executed during the course of a Case, then include a Process Task.

The referenced Process can contain a Script Task that will execute the script when triggered by the Case (see figure at right).



Handling Messages

Messages are not explicitly modeled in CMMN. They can only impact the Case through changes in a Case File.

A User Task could be used to receive or send a Message; however, this activity would be hidden to the Case Model. The Task could be used to update a Case File item (based on the Message).

Case File changes can be used to trigger Case Events causing activities and stages to be enabled, indirectly affecting the Case.

If it is important to explicitly view messaging between entities, then BPMN Collaborations can be used.

A Process Task can be included in the Case to link to a Process that will send or receive Messages (within the context of a Collaboration).

4.3.4. DMN Decision Models

- ❖ *Note there are sections below that define the relationships between DMN models and the other Clinical Pathway models.*

Shareable Clinical Pathway DMN models will utilize the Decision Service element (a rounded rectangle with two horizontal sections), which was added in DMN 1.2 and was not available for Version 1.0 of this Field Guide.

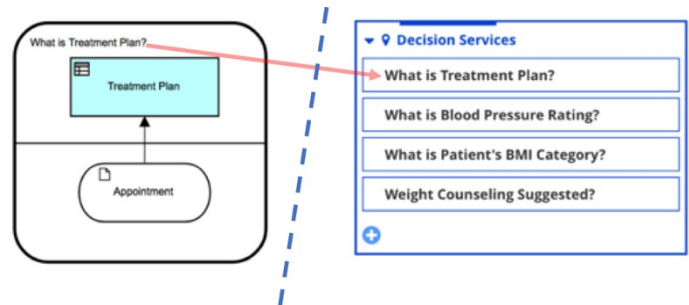
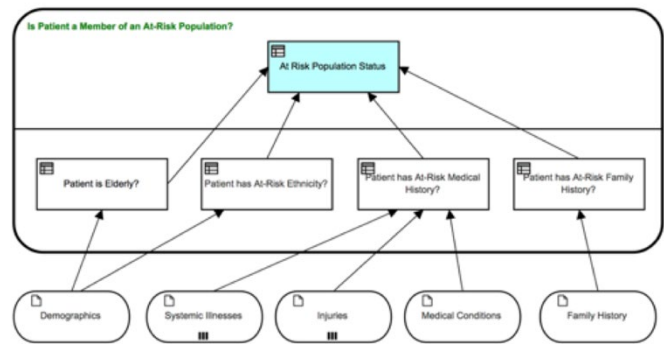
- The Decision Services will encapsulate all the elements that make up a service being called by a BPMN Business Rule Task or a CMMN Decision Task. This includes:
 - The inputs into the service;
 - The behavior of the service; and
 - The output of the service.

❖ *Note: DMN Decisions (rectangles) represent behaviors (e.g., decision tables or expressions) and outputs.*

- The name of the Decision Service should be in the form of a question (see figure below).

The upper section of the Decision Service object defines the output of the Service, which will contain one or more Decisions, however:

- For Shareable Clinical Pathways, the output of the Decision Service should be a single Decision (see figure at right).
 - This Decision will be color-coded light blue. This will make the Decision Service output more obvious. Further, it will be easier to identify the object that maps in name to a BPMN Data Object or a CMMN Case File Item.
- Other Decisions can be used within the Decision Service if the calculates are complex.
 - These Decisions can be placed in the lower section of the Decision Service Object or outside the object.
- Data Inputs to any of the Decisions of the Decision Service are placed outside the object, but have connectors extending to Decisions within the Decision Service.
- A DMN Decision Service will have a corresponding Services Item in the Library/5WH Model (see figure at right).

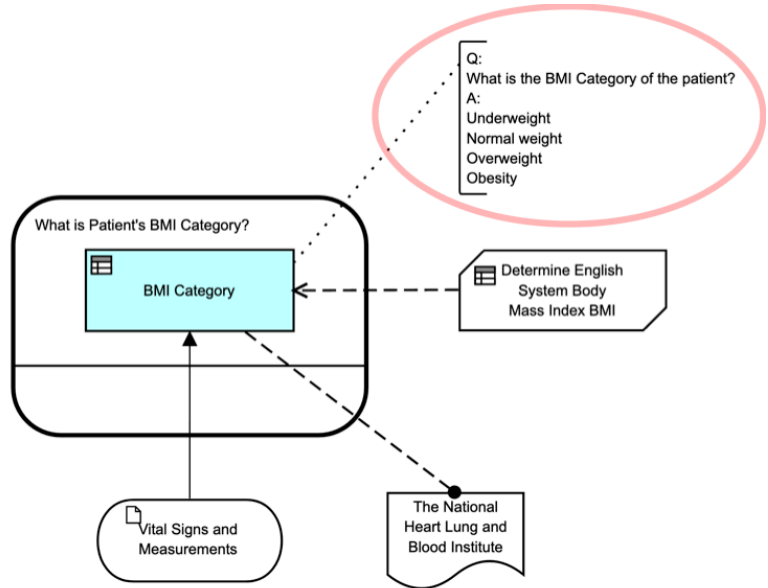


A Decision Requirements Diagram (DRD) for a Shareable Clinical Pathway will usually have multiple Decision Services. The Data Inputs and Decisions may be utilized across these Decision Services.

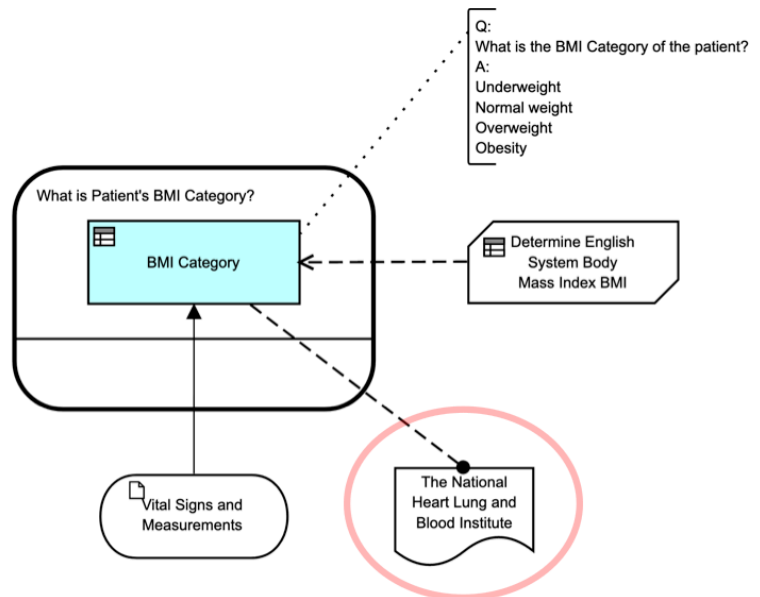
General Decision Modeling Styles

In general, a DMN Decision Service represents a question with a set of possible answers.

- An annotation can be used in the DMN model to document the question and answers for each Decision Object so that the reader of the diagram can understand the nature of the Decision (see figure at right).
 - The same question and answers can also be used as part of the definition of the DMN Decision. It is recommended that the initial development of the Decision start with the question and answers prior to actual decision logic.



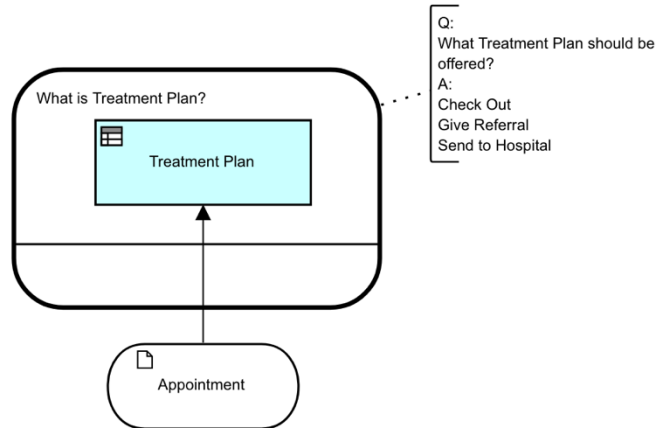
- When available, provide the external Knowledge Source that is used to create the Decision Logic.
 - For example, in the Hello Patient example, the BMI categories are defined by the National Heart Lung and Blood Institute (see figure at right).
 - Within the Knowledge Source object, a link is provided to the Website page that defines the categories.



Color Coding Decision Objects

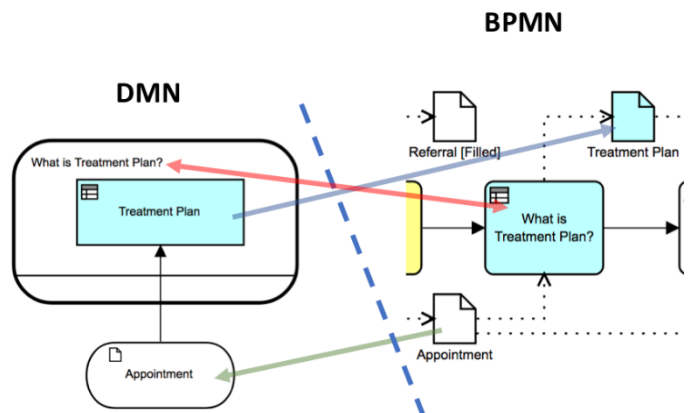
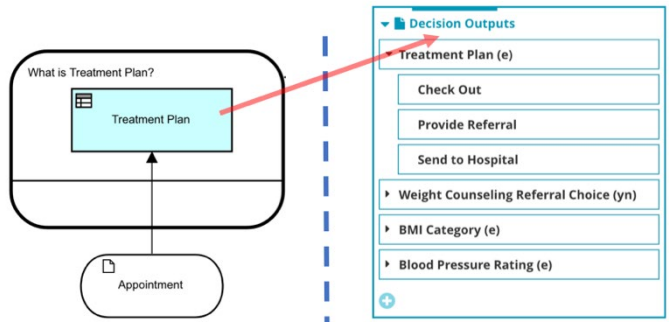
There is no specific use of colors defined in the DMN specification. It is the prerogative of Producers or modeling-tool vendors to make use of colors if they want to enhance the information presented in the diagrams. For the method and style being proposed in the Field Guide, we recommend that some color coding be added to the Shareable Clinical Pathway diagrams to highlight specific characteristics of Decisions. Our recommendations are detailed below.

- Light Blue:
 - Use this color to indicate that the Decision is the output of a Decision Service (see figure at right). As shown above, such Decisions map to BPMN Data Objects and/or CMMN Case File Items (which will also share the same color coding).
 - The use of this color coding will help the reader of the diagram to distinguish between Decisions that are connected to BPMN or CMMN models and the Decisions that do not have such a connection.

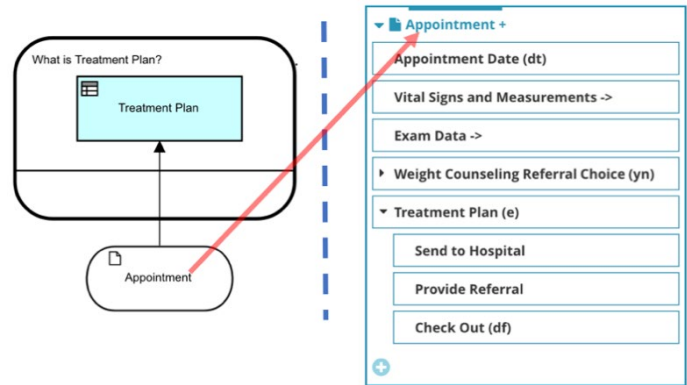


Including Data Elements in a DRD

- The data type for the output Decision Object should be a simple type (e.g., enumerated text, number, etc.).
- An output of a Decision Object (name and type) should have a matching Data element in:
 - The Situational Data Model Data Item (see figure at upper right).
 - A BPMN Data Object and/or CMMN Case File Item (see figure at lower right).
- A Data Input (name and type) should have a matching Data element in:
 - A BPMN Data Object and/or CMMN Case File Item (see figure at right).



- The Situational Data Model Data Group (see figure at right).



4.4. Relationships Between Clinical Pathway Models

4.4.1. Choosing between BPMN and CMMN

BPMN and CMMN have some overlapping capabilities. Thus, it is not always obvious which model is appropriate for each situation. In fact, there may be sets of activities that can be modeled in either modeling language.

One thing to consider is that the choice between BPMN and CMMN is not necessarily permanent. During the iterative development of a Clinical Pathway, it may be necessary to change one model into another. Thus, the choice between the two should not be over-thought. The following [Figure 23](#) provides a guideline for making the choice between BPMN and CMMN.

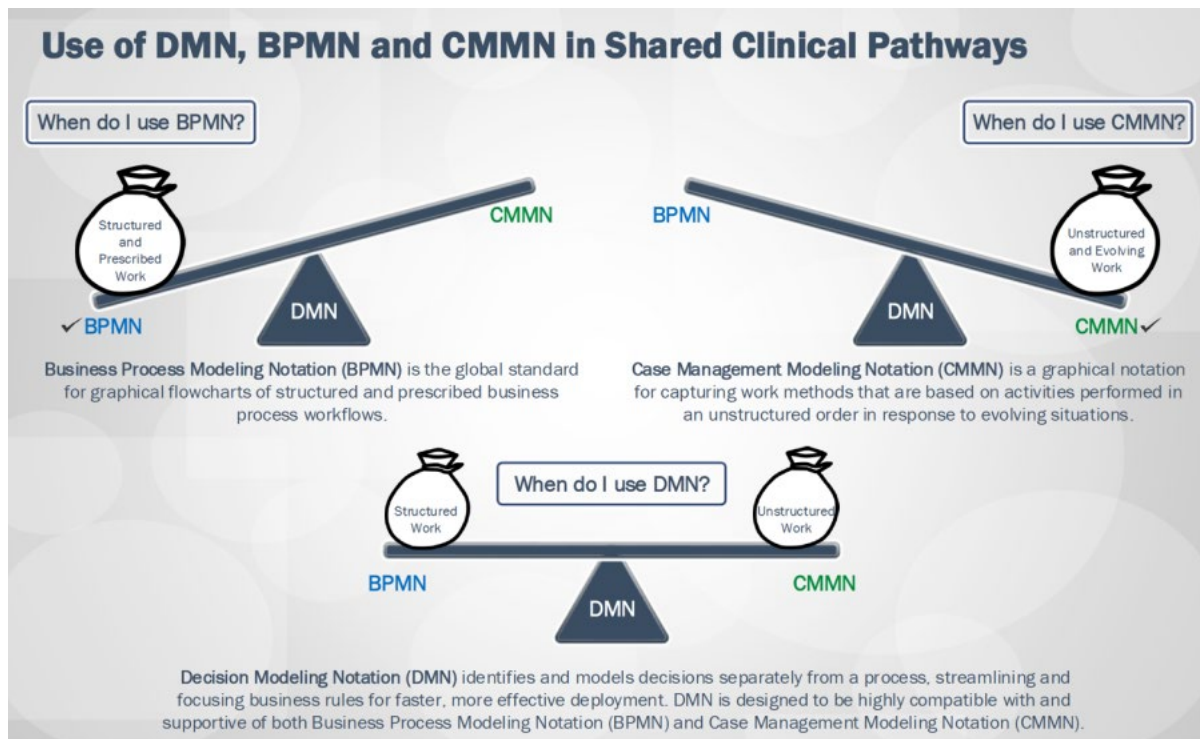


Figure 23 – DMN, BPMN and CMMN Shared Clinical Pathways

Use these guidelines for making the choice:

- If the Process is mainly structured (in flow), then use BPMN.
- If the Process is mainly unstructured, then use CMMN.
- For some situations, it will be clear that an unstructured Process behavior is required, so CMMN will be chosen. In other situations, it will be clear that a structured Process behavior better suits the activities, so BPMN will be chosen.

The SME for the Clinical Pathway should have a good idea about the nature of a particular set of Activities.

In some cases, the Producer will start with one of the languages but then will realize that the other language is more appropriate as the model is developed.

For example, if it turns out that a BPMN Process has a complicated structure of Gateways – to the point where the flow is hard to follow – then a Business Rule Task, supported by a DMN Decision, can replace a structure of Gateways.

Alternatively, a CMMN model might be more appropriate.

If a BPMN Process has a lot of parallel behavior where the ordering of the activities is not important, then a CMMN model might be more appropriate.

If a BPMN Process has a lot of activities that are optional (i.e., there is a gateway to a path that circumvents the activity), then a CMMN model might be more appropriate.

If a CMMN Model has too many dependencies, then maybe a BPMN model could be appropriate.

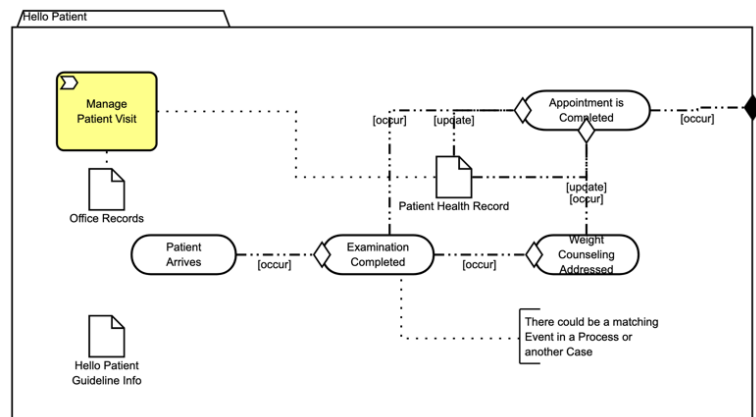
Other patterns can lead to modeling choices:

- A set of chained BPMN Gateways indicates that a DMN model could be used to replace some of the Gateways.
- If there are a lot of boundaries Events on a single BPMN activity, then CMMN diagram could be used to handle the event management.
- If the Process is not too complex, BPMN should have preference.
- BPMN is better supported by execution engines.

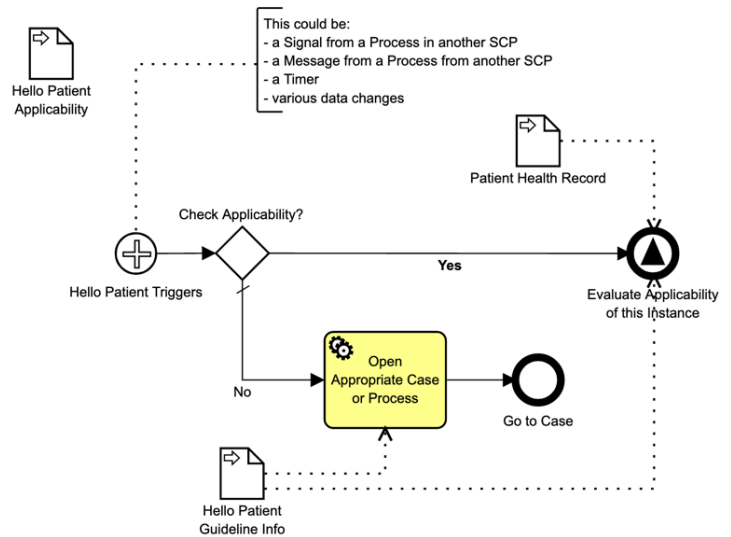
4.4.2. Use a Case (CMMN) at the Top of the Model Hierarchy

A Case model will provide management context and the Case File for the clinical pathway.

- The Top-Level Case model should be named for the Clinical Pathway.
- The Top-Level Case model should be simple and have only one behavioral element (see figure at right).
 - This element could be a Case Task or a Process Task.
 - The behavior structure and remaining hierarchy can be defined from the referenced Process behavior.



- The Top-Level Case model should contain the data (Case File items) relevant to the case as a whole.
 - This means that there might be CMMN Case File Items or BPMN Data Objects that are local to a specific level and not represented at the top level.
- Since there usually is a "chicken-and-egg" problem, a small "starting Process" using BPMN can be used to show how the Case gets started.
 - The starting Process should not be considered part of the Shareable Clinical Pathway.
 - It may be a snippet of another Process that identifies the context of how the Shareable Clinical Pathway is started.
- An External BPMN Process to identify the Start of a Shareable Clinical Pathway Case at right, displays a snippet of a BPMN Process that responds to the triggers of the Shareable Clinical Pathway and then initiates the top-level Case. A BPMN Process is needed to identify the starting of the pathway since CMMN does not provide a starting mechanism.



4.4.3. Connection between BPMN and DMN

Whenever the Producer creates a Business Rule Task, this task will be connected to a DMN Decision (see [Figure 24 – Mapping Between a BPMN Business Rule Task and a DMN Decision](#)).

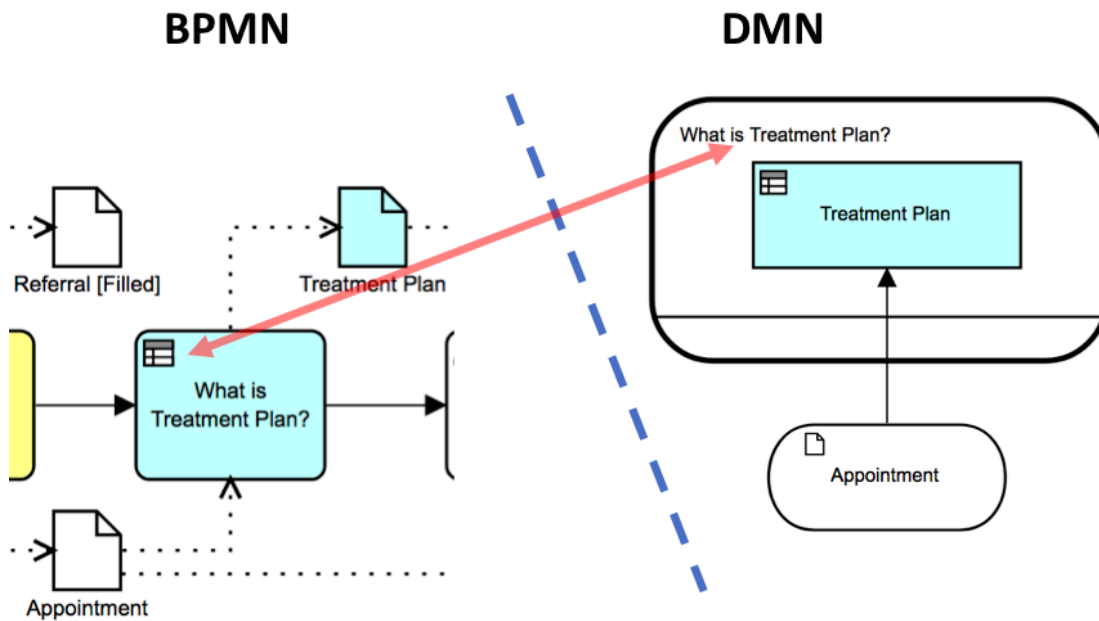


Figure 24 – Mapping Between a BPMN Business Rule Task and a DMN Decision

The BPMN data objects that are inputs into the BPMN Business Rule Task should match the DMN input data into the DMN Decision (see [Figure 25](#) below).

That is, the Artifact's name and structure (all types) should match across the diagrams.

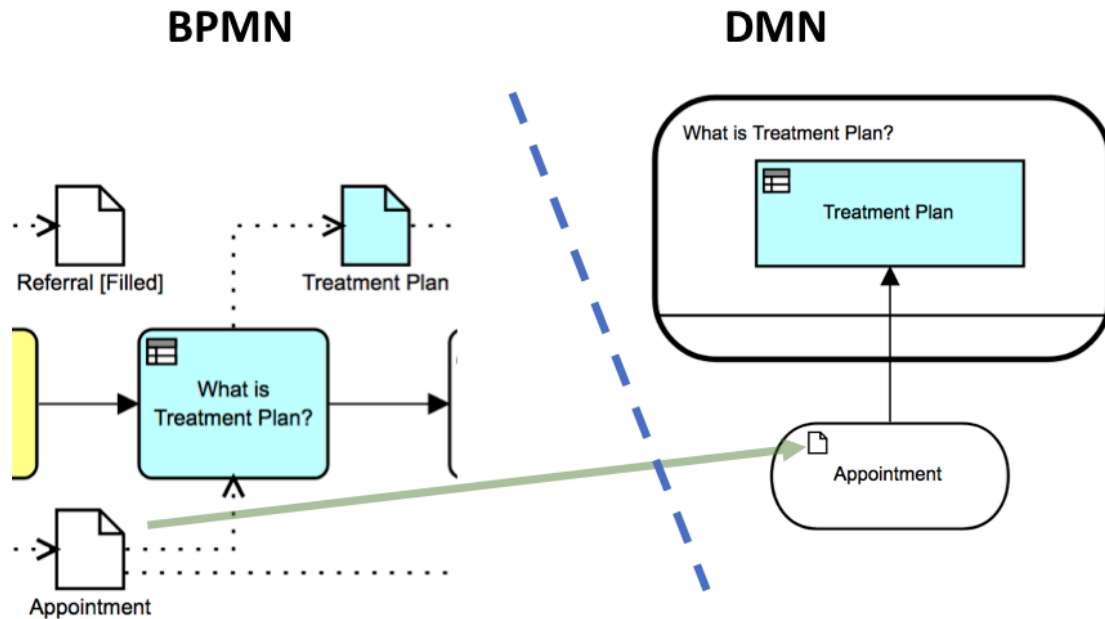


Figure 25 – Mapping Between a BPMN Data Object and a DMN Decision (Output)

The output to the Business Rule Task should match the output of the Decision.

The output should be an enumeration for a Decision that determines routing in BPMN (see [Figure 26](#) below).

There may be other DMN decisions that do not use enumeration outputs, which might not affect routing.

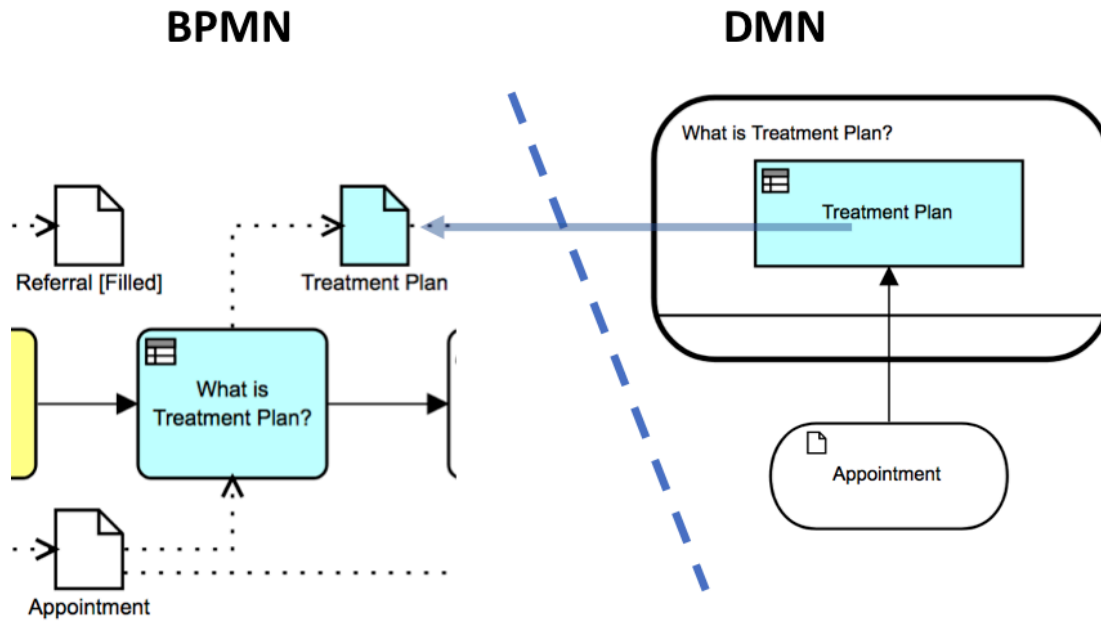


Figure 26 – Mapping Between a BPMN Data Object and a DMN Input

Prior to a BPMN routing Gateway, there should be a BPMN Task that determines the routing information (see Figure 27 below).

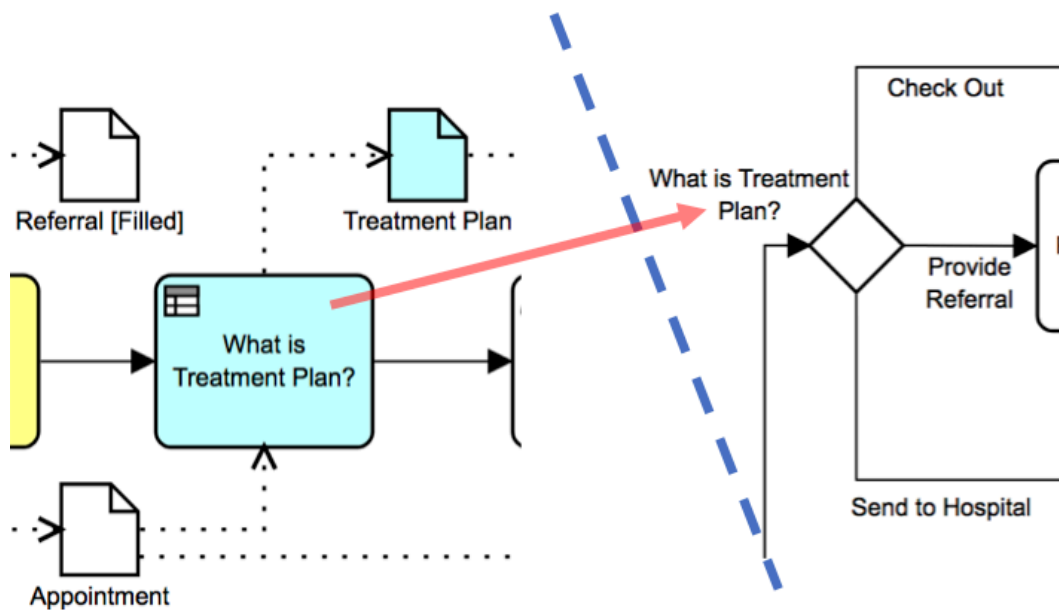


Figure 27 – Relationship Between a BPMN Business Rule Task and an Exclusive Gateway

This Task should provide the enumeration that determines the routing for the Gateway.

- ❖ Note that there might be other BPMN elements in between the decision-related Task and the Gateway that routes based on that Task (as in Figure 27 above).

This BPMN Task that provides the routing information could be Business Rule Task, User Task, Script Task, and Service Task.

Most of the time it will be a Business Rule Task.

The routing Gateway should be Exclusive or Inclusive.

The Gateway should not be Parallel, Event-Based or Complex.

For Inclusive Gateways, the output of the Decision should support one to many results.

The conditions and labels defined for the BPMN routing Gateway's outgoing Sequence Flows should match the enumerated values of the output of the BPMN Business Rule Task that came from the DMN Decision (see [Figure 28](#) and [Figure 29](#)).

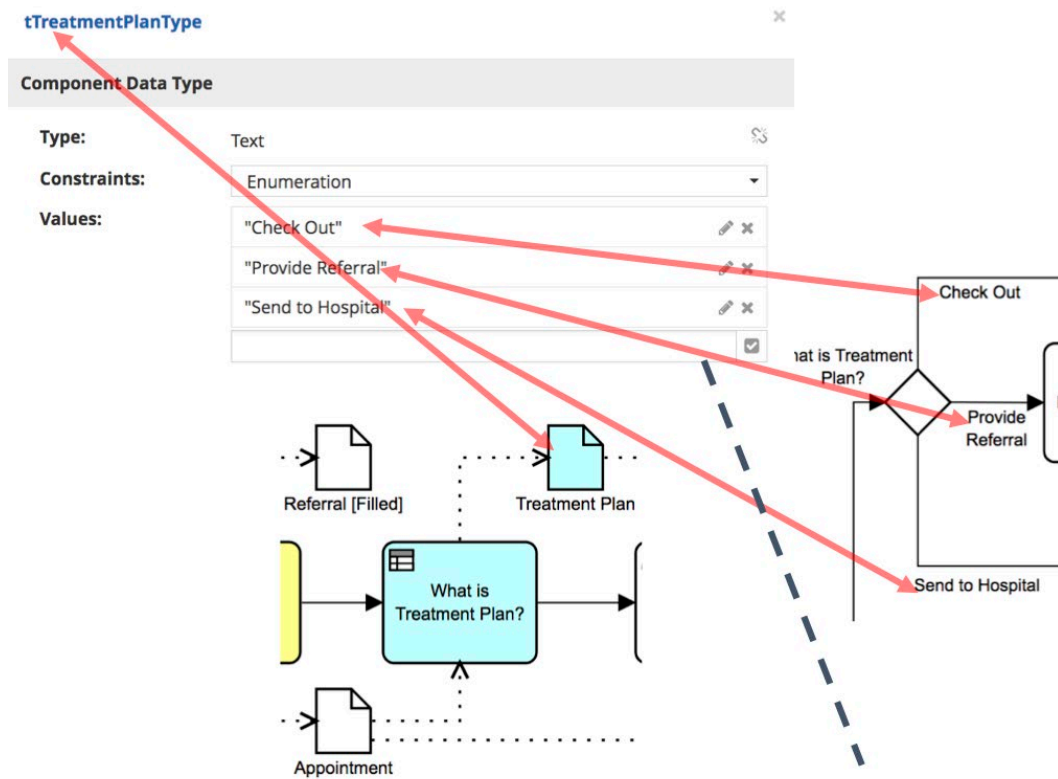


Figure 28 – Business Rule Task Output as Source of Data for Exclusive Gateway Expressions

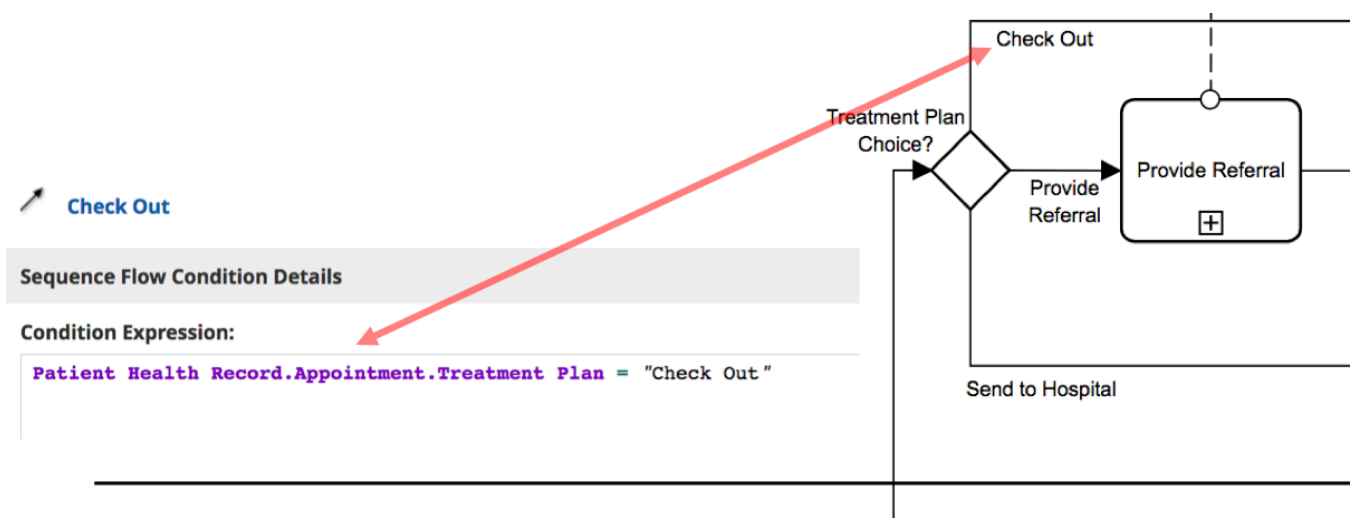


Figure 29 – An Example of an Exclusive Gateway Sequence Flow Expression

4.4.4. Connection between CMMN and DMN

Whenever the Producer creates a CMMN Decision Task, this task will be connected to a DMN Decision (see Figure 30 below).

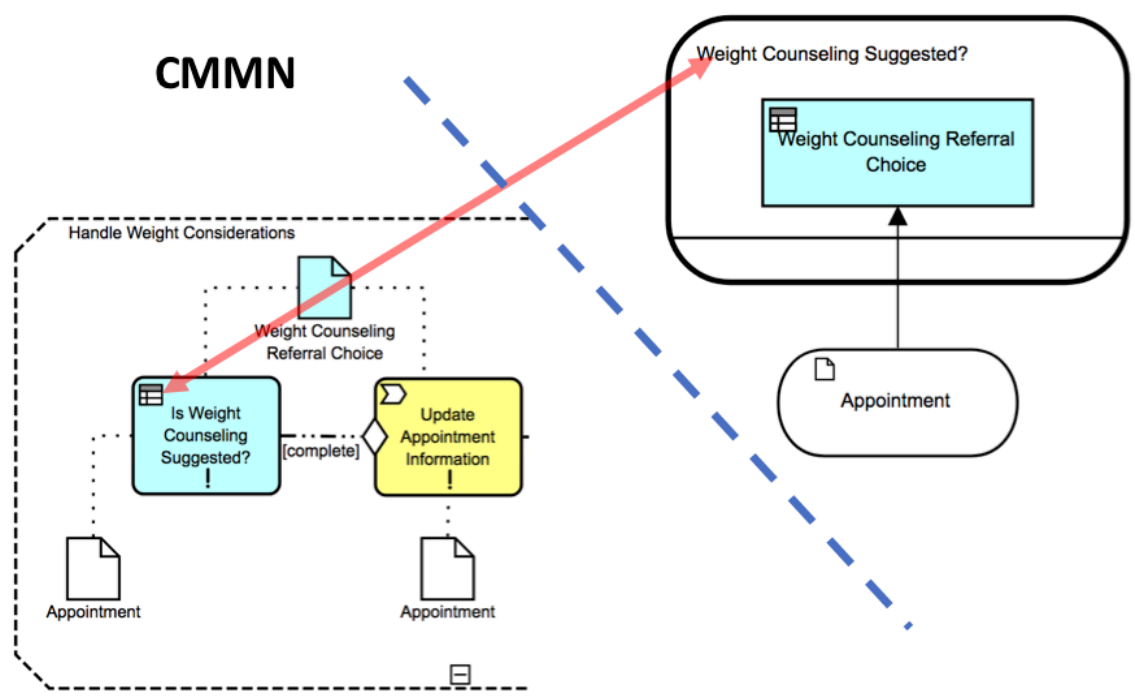


Figure 30 – Mapping Between a CMMN Decision Task and a DMN Decision

The CMMN Case File Items that are inputs into the CMMN Decision Task should match the DMN input data into the DMN Decision (see Figure 31 below).

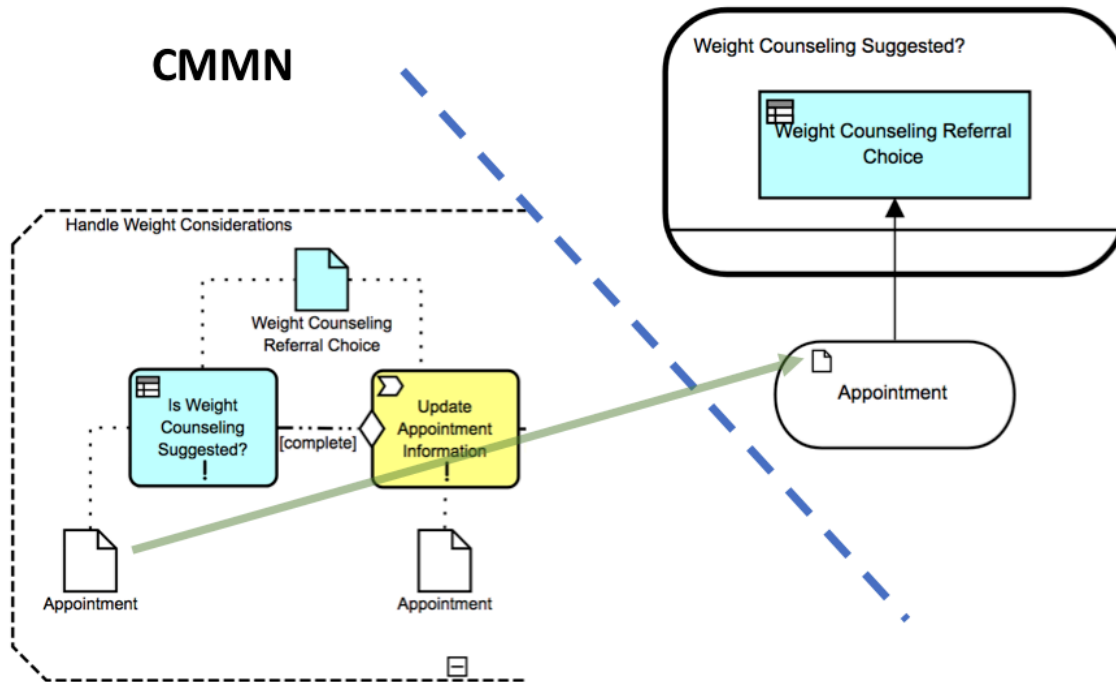


Figure 31 – Mapping Between a CMMN Case File Item and a DMN Input

A CMMN Case File should be updated based on the output of the DMN Decision (the output of the Task).

A CMMN entry or exit criterion can be triggered on the change to the CMMN Case File (see Figure 32 below).

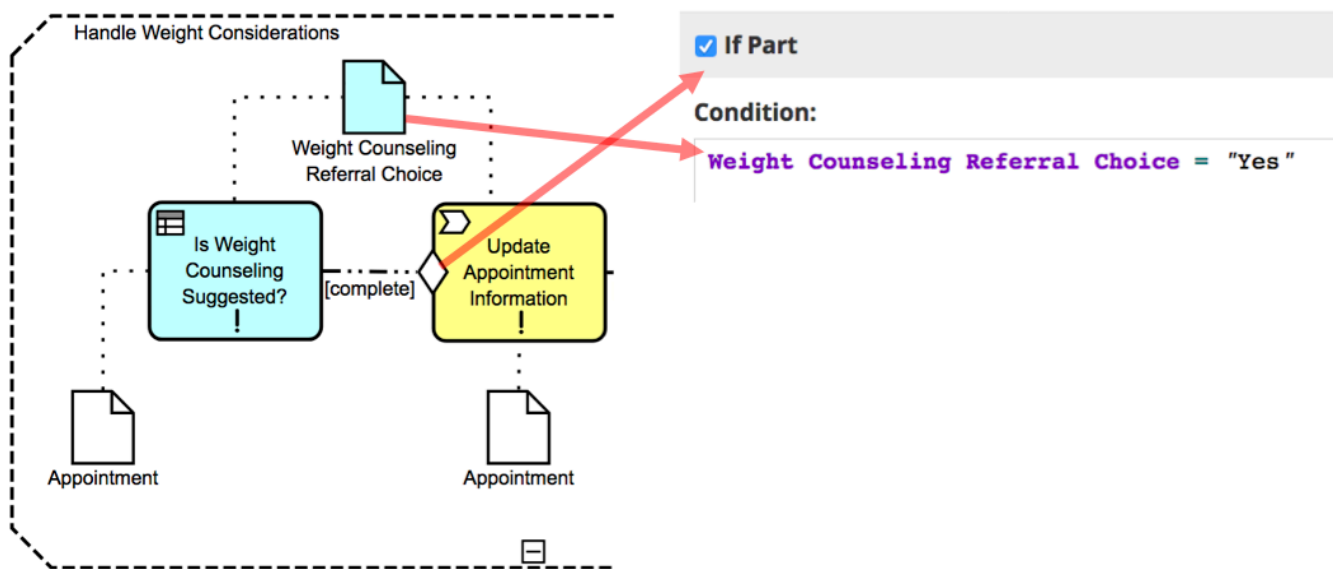


Figure 32 – An Example of an Entry Criterion If Part Expression

5. Consuming Models

5.1. Introduction

One of the benefits of modeling clinical pathways using standard languages semantics is the ability to share them across organizations. This section describes the process by which a receiving organization would use Shared Clinical Pathways: from discovery, to assessment, to an actual implementation.

5.2. Discovery Phase

The first step in sharing clinical pathways is discovering what pathways are available and determining which of them might be beneficial. This requires that the Shared Clinical Pathway include a robust set of metadata describing its subject, description, applicability, and provenance. An organization may decide it will not move on to the assessment phase for a variety of reasons, such as competing priorities or resource constraints. Even so, a well-documented clinical pathway may help readers acquire some knowledge that can help them, or their organizations deliver better healthcare.

5.3. Assessment Phase

The assessment phase includes the activities associated with evaluating the clinical pathway for fitness within a particular environment at the receiving organization. It should be approached by a team with a solid understanding of the organization's needs, resources, and existing workflows. Experts in the particular clinical or business problem being addressed should be included in this team.

5.3.1. Applicability

The applicability step determines whether some or all of the clinical pathway can be used within the receiving organization. Applicability is a factor of the clinical pathway itself and characteristics of the receiving organization. Applicability criteria for the care pathway include information about the context of use such as patient characteristics, provider characteristics, and care settings. Organizational factors to be considered include the existing clinical and technical skills; existing IT assets; internal and external policies and regulations that might affect the clinical pathway; and a business plan and analysis that factors in the costs of implementation as well as the benefits.

As described above, there are many factors that need to be considered. This Field Guide is focused on clinical pathways and process but how information is produced and consumed during these clinical pathways is a critical and nuanced part of this evaluation. Please see Appendix A – The Information Ecology of Clinical Care for more discussion about this area.

5.3.2. Simulation

Larger organizations may have the resources and the skills to perform simulations comparing their current states to one or more future states based on utilization of the clinical pathway. A number of the existing BPM toolsets provide functions that can assist in simulation. Simulations may be particularly valuable in determining the effects that adopting a particular process will have on organizational resources.

5.3.3. Acceptance

Once a clinical pathway has been deemed applicable and relevant cost and benefit relationships have been reviewed, the receiving organization may choose to incorporate a BPM into its business practices. Access to

these models is anticipated to include for-profit, nonprofit, and free/open-source approaches. Business transactions appropriate to the acquisition of the needed model are outside the purview of this guide.

5.3.4. Localization Phase

Once a model is acquired, it will need to be localized to the institution implementing it. Localization is the process by which the clinical pathway is adapted to the receiving organization's environment. Localization includes two components: mapping the concepts used in the pathway to local terminologies and modeling the local workflow processes.

Workflows: If the clinical pathway has been built according to the recommendations in this guide, it will differentiate between the clinical essence of the pathway and the local processes that can vary without changing the clinical intent. For example, the indications for ordering a blood transfusion are core to the clinical meaning of the pathway, while the process for ordering and obtaining the blood would be local to the receiving organization. The receiving organization must refine the shared clinical pathway by building out these local processes.

5.4. Information, Semantics, and Terminologies

Aligning the flow of information to support the clinical pathway is necessary to achieve the desired efficiency and outcomes. As part of this process, the expression of the clinical pathways in standard process modeling languages using healthcare standard semantics and terminologies facilitates the process of localization by enabling the receiving organization to effectively map the concepts used in the clinical pathways to local patient data. Concepts to be mapped include roles, resources, observations, interventions, diagnoses, etc. Basically, they are all of the "nouns."

5.5. Implementation Phase

The implementation of a BPM is typically the most demanding and expensive part of incorporating a business process. Choices will be made between automation and manual implementation. In many cases, a mixed model may be tried.

5.5.1. Automated vs. Manual Utilization

Depending on the existing capabilities available in the healthcare organization, the Shared Clinical Pathways can be automated, may be implemented manually, or the institution can implement a hybrid approach. In addition, there can be multiple standards that can be utilized for automated implementations. The following table identifies standards that might be used. For each standard, SCPs will strive to provide documentation; open-source tooling and content; and code libraries to simplify and reduce the implementation time and effort.

Table 3 – Approaches to the implementation of Shared Clinical Pathways: automated vs. manual implementation.

<u>Implementing Clinical Pathway Functionality</u>	<u>Automated Implementation</u>	<u>Manual Implementation</u>
Shared Clinical Pathways	Configuration dependent on availability of BPMN and CMMN Engines. Alternative approach is use of FHIR workflow resources such as Task and Plan Definition. Shared Clinical Pathways will be able to produce computable artifacts for BPMN and CMMN localizations. FHIR workflow resources are opportunities to generate appropriate code.	Manual process will require localization efforts to be focused on developing documentation and forms for and training of staff.
Publish and Subscribe Services	Communication approach for data and events using FHIR-based resources. Relevant information is exported from the EHR and consumed by subscribing applications triggering various application-specific behavior.	Workflow handoffs among participants can be handled using non-automated communication channels. An inbox/outbox approach may be used. Email services can be used. Alternative approaches such as trained administrative staff can also provide communication channels.
Data Services	Data services are used both for reading and writing data from and to the EHR. Clinical Pathways invoke standard APIs for FHIR Resources, internal Data Services, or other specifications.	The usual, local access to data is used to find (and store) the information necessary to manually execute the processes in the protocol.
Role Management Services	Clinical Pathways provide semantic mappings to CDA and FHIR role definitions.	Documentation for and training of staff for each role they may be asked to fulfill.
External Communication Services	For electronic messages, Clinical Pathways may provide semantic mappings for specification such as CCDA, FHIR, and HL7 V2 messages. Other mechanisms (email, web portals, etc.) may be used.	Appropriate fax, email, and regular mail may be used.

Clinical Decision Support Logic / Services	Multiple options available with OMG DMN, FHIR with FHIR Hooks and CQL, the Arden syntax, and others. And standards-based implementations with languages such as Drools and hybrid implementations, are also possible.	For manual localization, it may not be possible to implement some Clinical Pathway Decision Support Services. Simple ones can be implemented with appropriate documentation where tasks involve computations that can be done by humans without computer assistance
High Level Services (e.g. Order Services)	These services can be characterized as more complex than data services. The services should provide all of the functionality needed, such as allowing external applications to order a complex series of items. Extensions such as testing for drug-drug interactions and allergies or for bleeding risk should be easily incorporated.	These high-level complex services will need to be decomposed to be able to be supported by manual processes.

5.5.2. Standards-Based Technologies

Local Utilization is the methods and procedures that can be used to operationalize the Shared Clinical Pathways within an organization.

The following table describes some sample localizations of SCP features for use within an organization.

Clinical Pathway Functionality	Possible Implementation Approach
Business Process Management (BPMN, CMMN, DMN)	JBPMN, FHIR Plan Definition, CDS Hooks
Publish and Subscribe Services	FHIR Pub Sub
Data Services	FHIR Profiles
Role Management Services	JBPMN, FHIR Participant Resource
Communication Services	FHIR Pub Sub,
Clinical Decision Support Logic / Services	CQL, OMG Decision Logic
High Level Services (e.g. Order Services)	J2EE, HSSP Order Management Services
Terminology Services	SOLAR

The examples below are specific to the problems of 1) converting a CMMN model to a BPMN model; 2) managing semantics using taxonomies; 3) alternate ways of expressing decision logic; and 4) a terminology mapping example.

Business Process Management Example

If a Consumer of a Shared Clinical Pathway does not have an engine that supports CMMN, then it is possible to convert the CMMN Case Models of the Clinical Pathway into BPMN Sub-Processes.

There are some behavioral overlaps between CMMN and BPMN, so those overlaps can be mapped easily. For example, a performance dependency in CMMN is modeled like this (see [Figure 33](#) below):

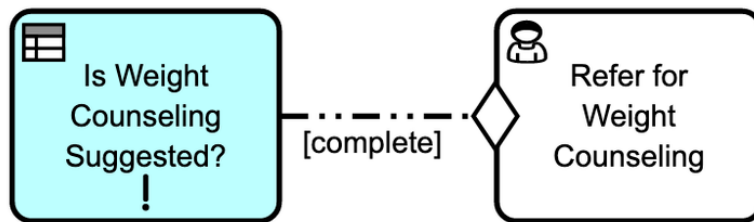


Figure 33 – A Performance Dependency in CMMN

The same performance dependency in BPMN is shown through a simple Sequence Flow (see [Figure 34](#) below):

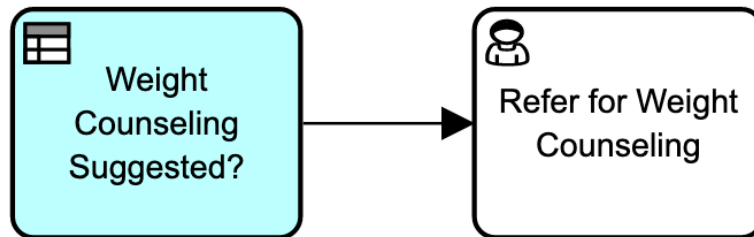


Figure 34 – A Performance Dependency in BPMN

Not all CMMN behaviors map in such a straightforward manner with BPMN. Some assumptions will need to be made about the behavioral relationships when creating the BPMN model. New activities and Gateways may have to be added to the model, along with additional data elements to take care of the lack of Performer control for initiating activities.

The [Figure 35](#) and [Figure 36](#) display a CMMN Case model and a matching BPMN Sub-Process. These two models will be performed in a manner that is very similar. All the details for the mapping between the two models are not defined here.

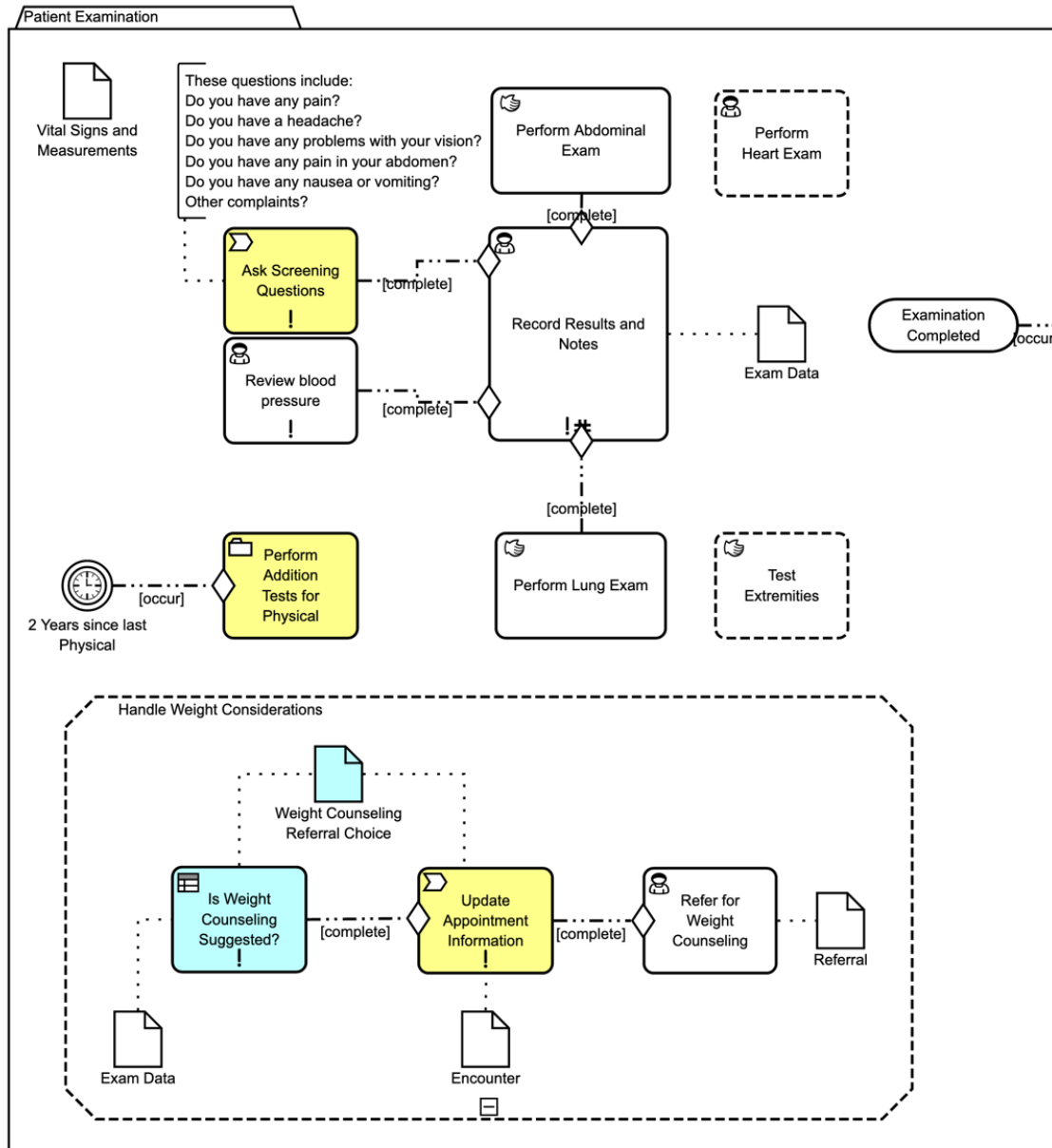


Figure 35 – CMMN Case Model of a Patient Examination

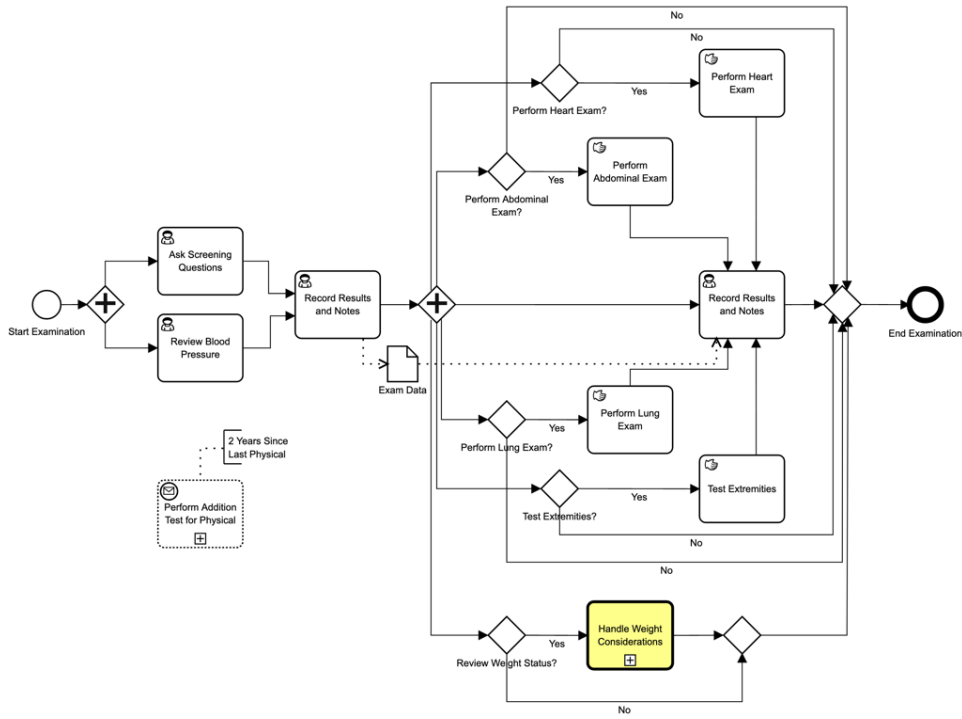


Figure 36 – BPMN Sub-Process Converted from CMMN Model of Patient Examination

- ❖ Note that the BPMN Ad Hoc Subprocess shares many characteristics as a CMMN Case model. The activities in an Ad Hoc Subprocess can be performed in any order or ignored as determined by the performers of that process. As you can see in the Figure 37 below, the Ad Hoc Subprocess is much simpler than a normal BPMN Sub-Process (seen in the Figure 36 above). However, execution engine support for the Ad Hoc Subprocess is less common than CMMN engines.

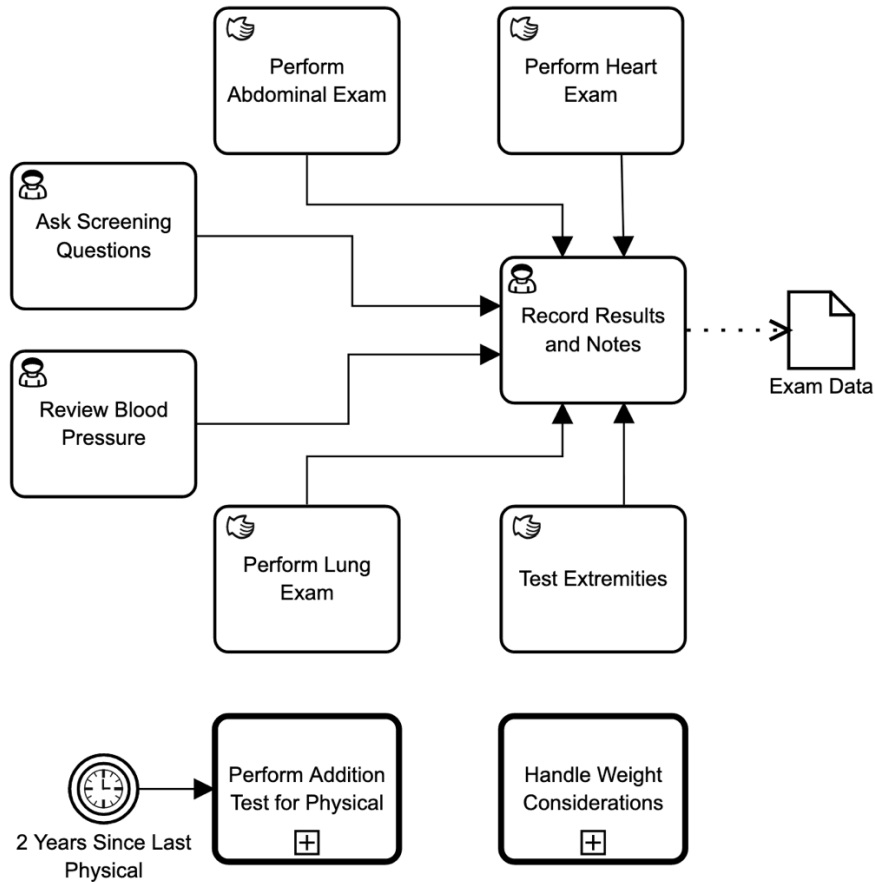


Figure 37 – The same Patient Examination Process modeled with a BPMN Ad Hoc Subprocess

Data Services Example

Integrating information into the workflow at the correct moment is crucial to effectiveness of the process in obtaining the goals of the SCP. Defining and understanding the semantics of the information needed is not an easy task but the SCP (as discussed in the checklist section) needs to provide this information through a taxonomy. There are multiple taxonomies, but we will look at using the SEER whose focus is on defining semantics of elements of information. (SEER MDMI/SEER)

The SEER based SCP would provide the following SEER compliant data object definition:

```

Patient
...
PatientAdministrationGenderCode
PatientBirthDateTIme
  
```

The SEER itself provides important link to existing standards allowing discovery of a standard based information definition such as US Core Patient FHIR (see profile) that could be used as an inline replacement of the BPMN data object and services. Additionally, the SEER is part of the MDMI specification that publishes executable transformation mappings of such specifications.

In our hello work example, the Get Patient Step would be replaced with a FHIR Rest API request for the US Core Patient resource and leverage the MDML mapping to produce the appropriate BPMN data object instance for the SCP to operate.

Clinical Decision Support Logic / Services Example

Decision points are a basic component of workflow definitions and, as such, an SCP will define trivial and complex decisions. The SCP will define a DMN for each of these decisions but in a particular mode decision for **IsPregnant**, the need to use a local version **IsPregnant** could be completed through the use of Clinical Quality Language (CQL). See (<https://ecqi.healthit.gov/cql>). The DMN would provide the inputs and the expected outputs from the decision but the actual execution of the decision would be within a CQL server.

The DMN for Is Pregnant would be:

Pregnancy Status
tPregnancyStatus
 "Pregnant", "Not Pregnant"

inputs				outputs	annotations
U	Patient Demographics.Gender	Pregnancy Conditions.Clinical Status	Pregnancy Conditions.Verification Status	Pregnancy Status	Description
	Text "Male", "Female", "Undetermined"	Text "Active", "Inactive"	Text "Confirmed", "Unconfirmed"	<i>tPregnancyStatus</i> "Pregnant", "Not Pregnant"	
1	"Male"	-	-	"Not Pregnant"	
2	"Undetermined"	-	-	"Not Pregnant"	
3	"Female"	"Inactive"	-	"Not Pregnant"	
4	"Female"	"Active"	"Unconfirmed"	"Not Pregnant"	
5	"Female"	"Active"	"Confirmed"	"Pregnant"	

while the similar approach for CQL is:

```
define "Pregnancy Conditions":
  [Condition: "Pregnancy"] C
  where C.clinicalStatus = 'active'
  and C.verificationStatus = 'confirmed'

define "Is Patient Pregnant":
  Patient.gender = 'female'
  and exists ("Pregnancy Conditions")
```

Terminology Services Example

A large portion of semantics and interoperability is the effective and accurate use of terminologies. Mapping between such terminologies is not optimal but there are times when your only choice is to map from one vocabulary to another.

In our hello world example, the data element Immunization Administered Medication Code as part of the SEER-based SCP declares that the code should be **SNOMED CT** while the local data services used **RxNorm**, which then requires a transformation between them. The management and definition of these mappings is beyond the

scope of this document but the use of terminology services such as FHIR (SEE FHIR Term) is an appropriate example of localizing the SCP to provide it the correct value to accurately and effectively execute the workflow.

6. Appendix A – The Information Ecology of Clinical Care

Information is a critical resource for the practice of clinical healthcare. We can achieve significant gains in quality and efficiency when the flow of information matches appropriate workflow of care. But when information flow contradicts, it can rearrange clinical workflow by accident rather than by design.

Information constrains care activity in ways that are analogous to physical resources: Missing information causes delays to begin activities; Performing an activity without complete and accurate information increases the risk of medical errors; And, Better information can reduce the time and effort needed for doctor and staff to perform care.

We need to clarify some distinctions that are important to health information technology to reflect the constraints of information accurately in models of care.

- The term "health information technology system" is something of a misnomer because its contents are actually produced by a combination of the manual and cognitive activities of clinical personnel as well as the functions of computers. Consequently, the information needed for care resides or gets changed in a variety of media. Important clinical information resources include equipment, paper notes, paper records, electronic medical record systems, and white boards. These will remain important in clinics and hospitals for the foreseeable future. Their contents often overlap and can be highly dynamic, leading to serious problems of accuracy, synchronization, and burdensome manual integration. They must be captured for model completeness and also so they can be addressed in system redesigns.
- The variety of information resources includes people and even inanimate objects. Clinical colleagues and patients themselves have long been key information resources. Patients have dual roles as information resources during exams vs. their obvious role as the object of care activity. Inanimate objects in the observable environment represent information that impacts planning and decision making (e.g., "Exam room #6 is vacant now," or, "The ER waiting room is SRO.") The dual role of clinicians as performers of activity vs. information resources must be reflected in an accurate model. Removing the burdens for clinicians to transform and remember large amounts of complex information is an important purpose of health information technology.
- Information is often more than a single datum. As just one example, many data have to be filtered and processed to detect "ventricular arrhythmia." That single term provides information that is actionable to make decisions. The level of granularity to capture requirements for information is typically much less detailed than data requirements to satisfy them. The level of granularity for BPM models that exposes the "what and where" of information use can be a good heuristic to decide how much activity detail to show.
- It reduces confusion to distinguish two roles that information plays. The roles are determined by activity context. For example, a diagnosis can be the abstract object of cognitive clinical work when a doctor is developing it. That diagnosis can then be an information resource for subsequent activity, such as when it is needed to develop a treatment plan of orders. The orders, in turn, become key information resources to carry out physical care activity on the patient. Notes on carrying out orders and patients' response are developed during care, then become an information resource for revising the treatment plan and so on. It's often more clear to model the creation of an information resource with its own sub-process: one that is scoped to begin with the triggering event and ends when the information resource reaches its goal state. Subsequent revision of that information resource may re-use the sub-process, or it may occur as a byproduct of other, later tasks.

- The flow of information about patient care is not the same as the workflow of care for the patient. They often take parallel flows. There are many examples where the flows diverge when images, tests, or consults are done on the patient and analyzed as abstract work objects within their own sub-workflows while the workflow of the current care plan continues on the patient. The workflow for analyzing the tests, etc., should be modeled as coordinated support systems. The flows converge when the results are used as information resources.
- Patient care requires physical resources that are often in high demand (e.g., scarce equipment or skilled personnel). Information about their capability and availability are key parts of a critical information flow that is needed to plan, schedule, and coordinate patient care.

These aspects of the information eco-system of a clinical environment are fundamentally important for any model to represent the way clinical care is performed. Since information constrains activity, workflow models need to reflect the constraints of the information needed by tasks, the information resource that provides it to tasks, and where it goes if values are changed or aggregated. Information flow that is indexed to tasks can clarify precision information requirements for coordination, precision interoperability, and opportunities to apply information technology that might otherwise go overlooked.

In summary, there are five reasons for reflecting the usage and change of information in models of clinical care:

1. Clinical healthcare depends on information that is accessed or changed by a wide variety of resources, not only by computers;
2. Valid data requirements should be derived from and prioritized by clinical need for information;
3. Information is often developed as an abstract object of cognitive clinical work, and then serves as a key resource for subsequent care activity;
4. The strong interdependency of information and activity makes reviewing activity models a good technique to elicit information requirements, and vice versa; and
5. Better information resources should reduce the amount of physical resources needed for care, especially the energy and scarce time of busy clinicians.

7. Appendix B – Design Patterns

7.1. DMN: Simple Scoring Algorithm

7.1.1. Description

The simple scoring algorithm is a specialization of a quantitative decision. It takes multiple inputs, assigns an integer value to each, and sums the results to arrive at a score.

7.1.2. Problem

In medicine there are a large number of simple algorithms used to assess risk, assign probability to various conditions, and predict outcomes. One common form of these algorithms is based on a "scorecard." (See also: <http://dmg.org/pmml/v4-3/Scorecard.html> predictive models). The models are formulated in terms of a (usually brief) list of relevant clinical findings. Each of these findings is associated with a value (typically a small integer) and the scoring algorithm works through the simple expedient of adding together the values of all of the positive findings and testing the result against a threshold. Because of their pure computational nature, such algorithms can be modeled as DMN decisions.

For example, The Revised Geneva Score is a score used in the diagnostic workup of possible pulmonary embolism (PE). A group of eight findings frequently associated with PE are each assigned an integer weight (see [Figure 38 – Patient with Suspected PE](#)). The clinician sums the weights of the positive findings and uses the resulting score for further decision making. If the score is greater than or equal to 11, an imaging exam is indicated. If less, a blood test (the D-dimer) is used to further assess the probability of PE. [Figure 38](#), "Patient with Suspected PE," shows an algorithm for the workup of suspected pulmonary embolism. The initial testing decision is based on a score produced by adding the values associated with the findings that are positive. Totals under 10 lead to a blood test (the D-dimer); totals of 11 or greater suggest the need for a definitive radiology exam (the computed tomography-pulmonary angiogram (CTPA)). The graphic goes on to describe further diagnostic decision making after the initial testing decision has been made.

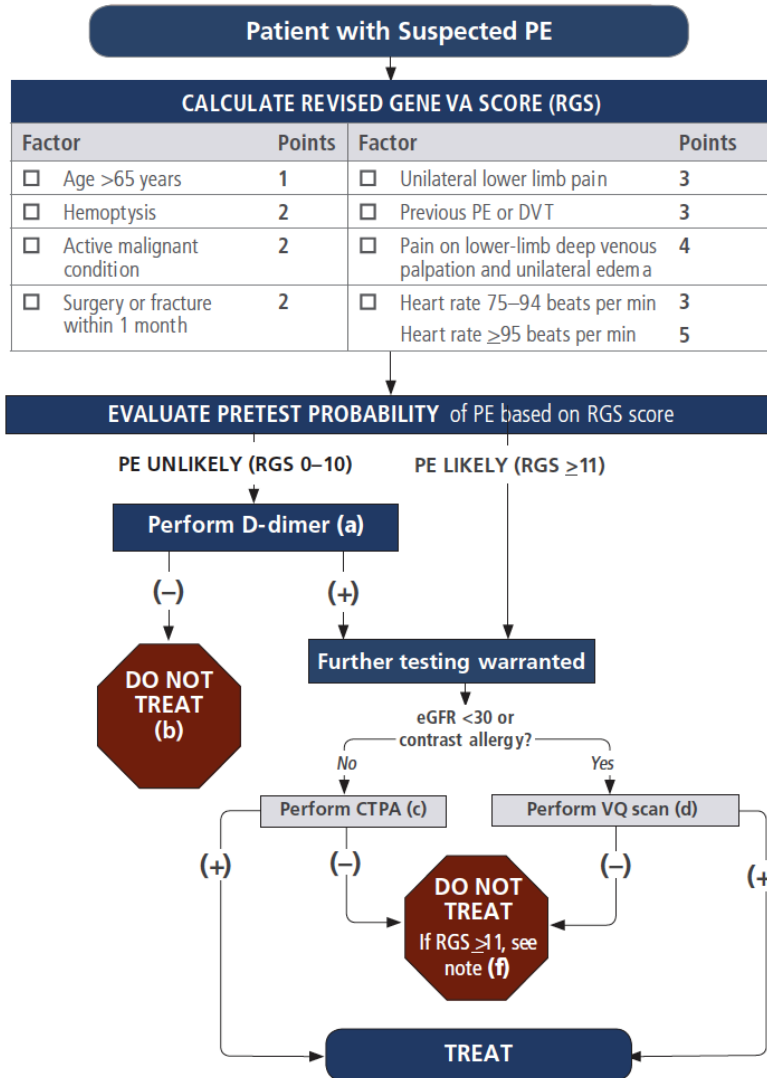


Figure 38 – Patient with Suspected PE⁸

7.1.3. Applicability

This pattern applies under the following conditions:

- Pure flow of information that takes multiple inputs and maps each one to a numeric value, based on a defined rule;
- The numeric values are aggregated into a numeric score;
- No "side effects" other than the evaluation of the score; and
- The collection of the inputs, as well as the use of the outputs, are outside the scope of the model.

⁸ Used with permission from Intermountain Healthcare. © 2012 Intermountain Healthcare. All rights reserved.

7.1.4. Pattern

The scoring algorithm is encapsulated within a single Decision node. Model relevant findings are indicated as data inputs to the decision. The scorecard is modeled as a vertical decisions table with a *Collect (sum)* Hit Policy. [Figure 39](#) shows the simplest form of the DRD. This pattern shows a generic Decision Requirements Diagram displaying the input of a series of simple variables into a scoring algorithm. A scoring algorithm compatible with risk scores (e.g., the RGS) is displayed in [Figure 40](#). In this table, for each row whose rule evaluates to "true," the output value will be added to the sum representing the total score for the table. If available, any reference to the algorithm logic should be modeled as a Knowledge Source attached to the main Decision node.

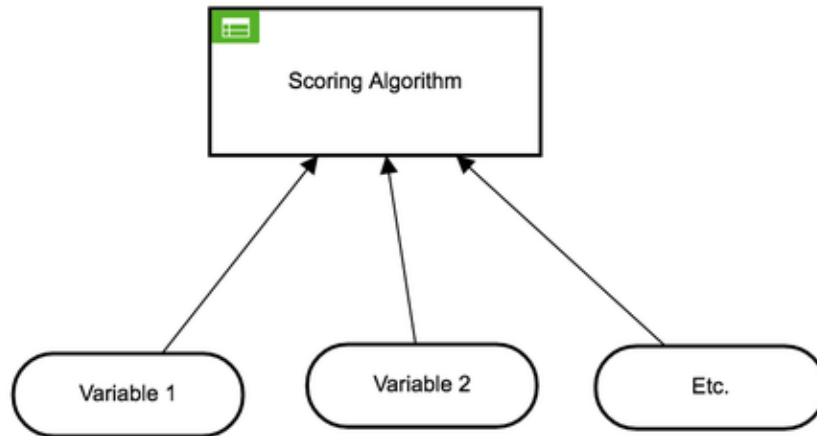


Figure 39 – the simplest form of the DRD for this pattern

A decision table that uses the *Collect* hit policy with the sum operator is displayed in [Figure 62](#). It shows a pattern for a table-based scoring algorithm that produces a sum of the numbers in all of the rows where the individual rules come true. This represents a common approach to risk scoring for medical conditions. In this table, for each row whose rule evaluates "true," the output value will be added to the sum representing the total score for the table.

Scoring Algorithm						Exit Advanced Mode	Show DRD	
Decision_13nychf								
C+	Input +			Output +				
	Variable 1	Variable 2	Etc	Score Component				
	string	string	string	integer		Annotation		
1	"Present"	-	-	"Number"	-			
2	-	"Present"	-	"Number"	-			
3	-	-	"True"	"Number"	-			
+	-	-	-	-	-			

Figure 40 – Table Representation of PE Decision

7.1.5. Specific Example

The [Figure 41](#) and [Figure 42](#) below display the DMN model for the Revised Geneva Score. [Figure 41](#) shows a Decision Requirements Diagram for the Revised Geneva Score. Note one change from the algorithm depicted above. The seventh variable has been decomposed into two separate variables: "Pain on Lower Limb Deep Venous Palpation" and "Unilateral Lower Limb Edema." This change is reflected in the rules shown in the decision table in [Figure 41](#). In particular, [Figure 41](#) (Revised Geneva Score DRD) shows the DRD for the Revised

Geneva Score. Figure 42 (Revised Geneva Score Decision Table) depicts the decision table used to calculate the RGS.

- ❖ Note the use of the Collect hit policy with the sum operator to indicate that the points in the outcome column will be summed for all rules that evaluate positive.

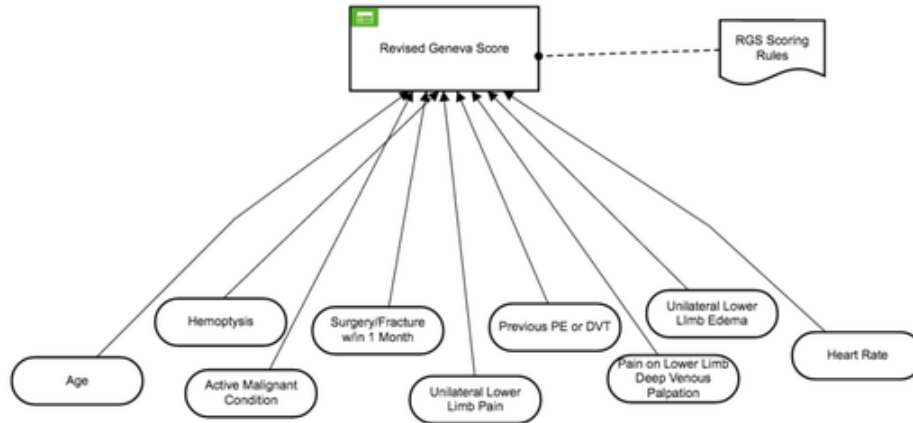


Figure 41 – Revised Geneva Score DRD

The first six rules in Figure 42 are based on a single finding whose presence is tested for. The seventh rule requires the presence of two findings and rules eight and nine test different ranges of the heart rate.

Revised Geneva Score											
C+	Input +									Output +	
	Age	Hemoptysis	Active Malignant Condition	Surgery/Fracture w/in 1 Month	Unilateral Lower Limb Pain	Previous PE or DVT	Unilateral Lower Limb Edema	Pain on Lower-Limb Deep Venous Palpation	Heart Rate	Points	Annotation
	double	string	string	string	string	string	string	string	integer	integer	
1	>65	-	-	-	-	-	-	-	-	1	Age > 65 worth 1 point
2	-	"Present"	-	-	-	-	-	-	-	2	Hemoptysis Present
3	-	-	"Present"	-	-	-	-	-	-	2	Malignant Condition Present
4	-	-	-	"Present"	-	-	-	-	-	2	Surgery or Fracture Present within the Last Month
5	-	-	-	-	"Present"	-	-	-	-	3	Lower Limb Pain Present
6	-	-	-	-	-	"Present"	-	-	-	3	History of PE or DVT Present
7	-	-	-	-	-	-	"Present"	"Present"	-	4	Lower Limb Tenderness and Edema Present
8	-	-	-	-	-	-	-	-	[75..94]	3	Moderately Elevated Heart Rate
9	-	-	-	-	-	-	-	-	>=95	5	Significantly Elevated Heart Rate
+	-	-	-	-	-	-	-	-	-	-	-

Figure 5: The decision table for the Revised Geneva Score. The first six rules are each based on a single finding whose presence is tested for. The seventh rule requires the presence of two findings and rules eight and nine test different ranges of the heart rate.

Figure 42 – Revised Geneva Score Decision Table

7.2. DMN: Quantify – Interpret – Recommend (QIR)

7.2.1. Description

The Quantify – Interpret – Recommend (QIR) pattern is a grouping of separate, but closely chained, pure cognitive processes. Because of their correlation, they can be modeled as individual Decisions or composed into one complex Decision.

In general, a quantitative decision takes multiple ("sensorial") inputs and aggregates them to generate a quantitative output. This quantitative output is then interpreted into a qualitative observation ("belief") that, in turn, drives (the "intent" of) an agent's action, or a recommendation thereof.

This is a generalization of the "Simple Scoring" pattern.

7.2.2. Problem

Some questions do not yield a finite number of qualitative, categorical answers but, rather, a quantitative, continuous value based on the complex aggregation of multiple diverse inputs that contribute in different roles and capacity, possibly with different weights. To be represented, these complex functions require possibly complex mathematical and/or statistical models, such as regression models or neural networks.

These quantitative predictions or estimates are used as assessments, to evaluate something about the patient that is not directly observable, and/or to better inform decisions regarding actions or interventions.

For example, the process of estimating the body mass index (BMI) of a patient can be modeled as quantitative decision corresponding to the simple question, "What is the patient's body mass index?" The resulting piece of information – a number – is not particularly useful on its own but is used by the following step, a classification cognitive task, whose corresponding decision might be, "What kind of body does the patient have?" The possible answers could be "underweight," "normal," "overweight," or "obese." This classification can be further used (e.g., to inform the choice of the best dietary and/or exercise program). Similarly, The CHA2DS2-VASc score is a quantitative decision that yields a score that is interpreted as the rough estimate of the likelihood of a patient's having a stroke. That, in turn, is used as the basis for deciding whether to prescribe an anticoagulant.

7.2.3. Applicability

This pattern applies when:

- Observe-Assess-Deliberate cycle, or subsets thereof;
- Multiple inputs are mapped to quantitative values, which are in turn aggregated by a predictive model;
- A (qualitative) interpretation allows to assess and/or predict some aspect that is not otherwise directly observable;
- The interpretation is used to determine the next best course of intervention; and
- The actual execution – by intervention or communication – is out of scope.

7.2.4. Pattern

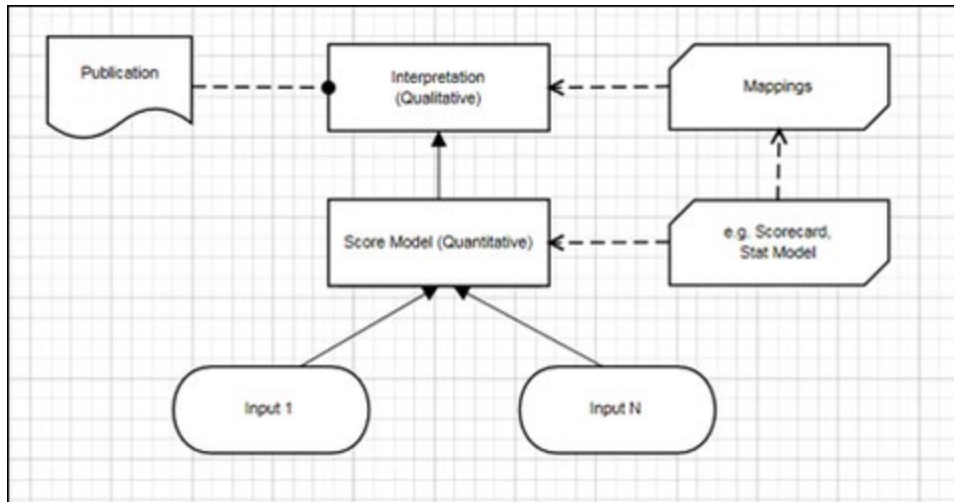


Figure 43 – Generic Decision Requirements Diagram illustrating the quantify/interpret pattern

Model the aggregation as a Decision with multiple data Inputs, and a Business Knowledge Model element that defines how the inputs should be aggregated. Notice that a decision table may not be expressive enough, in general, to define this model so other languages (e.g., PMML) could be considered.

The output of this first decision becomes a requirement for (and thus informs) a second-tier assessment/prediction Decision, which has an explicit Business Knowledge Model with mappings from (the value returned by) the quantitative decision to the qualitative classification or categorization. Reference material can be modeled as a Knowledge Source.

Interpretation of Score			Exit Advanced Mode	Show DRD
Decision_Or1qpy9				
U	Input +	Output +		
	Output of Scoring Algorithm	-		
	Integer	string		
			Annotation	
1	"> X"	"Low Score Response"	Response to a Score LT X	
2	"<= X"	"High Score Response"	Response to a Score GE X	
+	-	-		

Figure 44 – Interpretation of Score Decision Table

Figure 44 illustrates a test score produced by a scoring algorithm using a simple threshold. Its output is the interpretation of the quantitative decision.

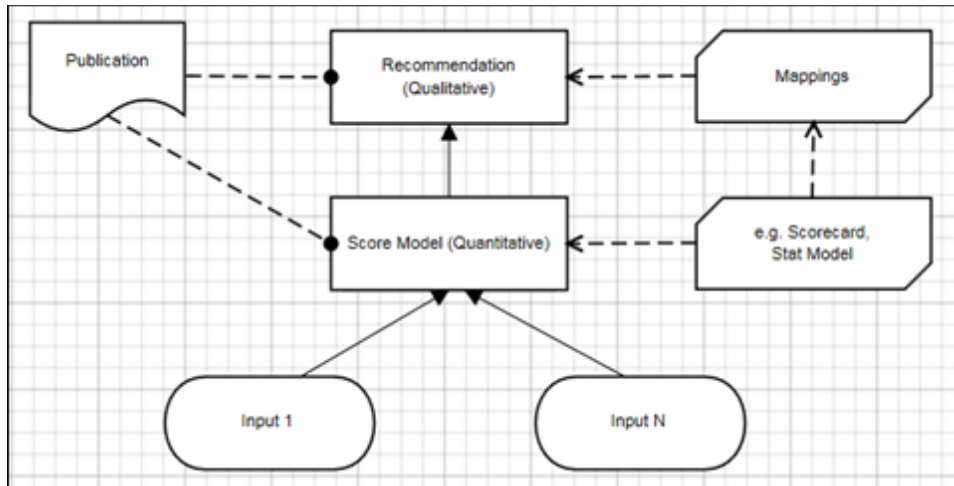


Figure 45 – Recommendation decision based on a quantitative sub-decision

Score	Output
"Score<X"	"Action A"
"X<= Score<Y"	"Action B"
"Y<=Score"	"Action C"

Figure 46 – Generic Decision Table

Model the quantitative decision with multiple inputs, and a knowledge model that defines the mathematical formula used to arrive at the outcome based on those inputs. Use the outcome of the quantitative decision as an input into a recommendation decision. Create a knowledge model with mappings from the value returned by the quantitative decision to a list of alternative recommendations.

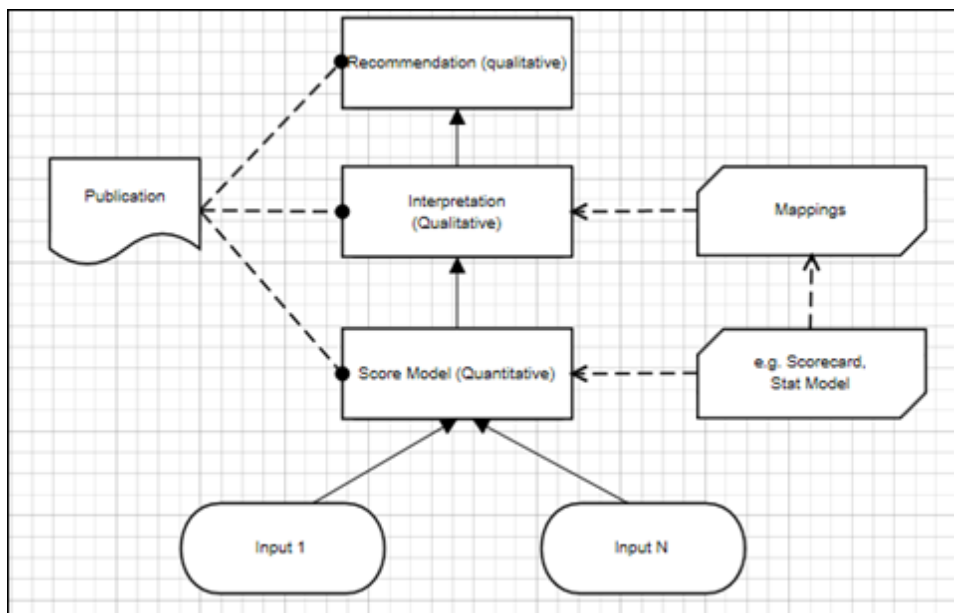


Figure 47— Quantify Interpret Recommend

The [Figure 47](#) above (Quantify Interpret Recommend) illustrates a recommendation decision based on an interpretation sub-decision, which in turn is based on a quantitative sub-decision.

Recommendation (qualitative)	
Interpretation (Qualitative)	Recommendation (Qualitative)
"Category 1"	"Action A"
"Category 2"	"Action B"
"Category 3"	"Action C"

Figure 48 – Interpretation / Recommendation decision table

Model quantify-interpret pattern as described above. Model a third decision for the recommendation, with the outcome of the interpretation decision as an input.

7.2.5. Specific Example

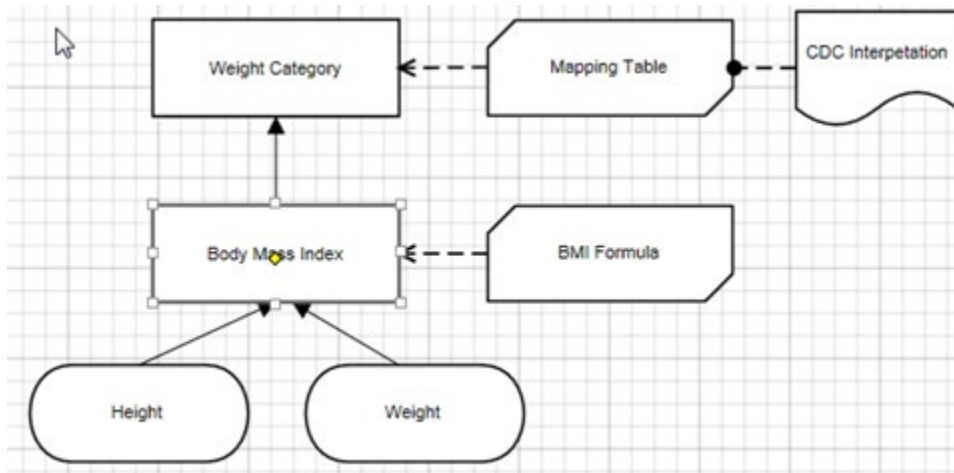


Figure 49 – Quantify – Interpret: BMI

The [Figure 49](#) above (Quantify – Interpret: BMI) illustrates that the body mass index is calculated based on height and weight. The resulting numeric output is then used to classify the patient as underweight, normal weight, overweight, or obese.

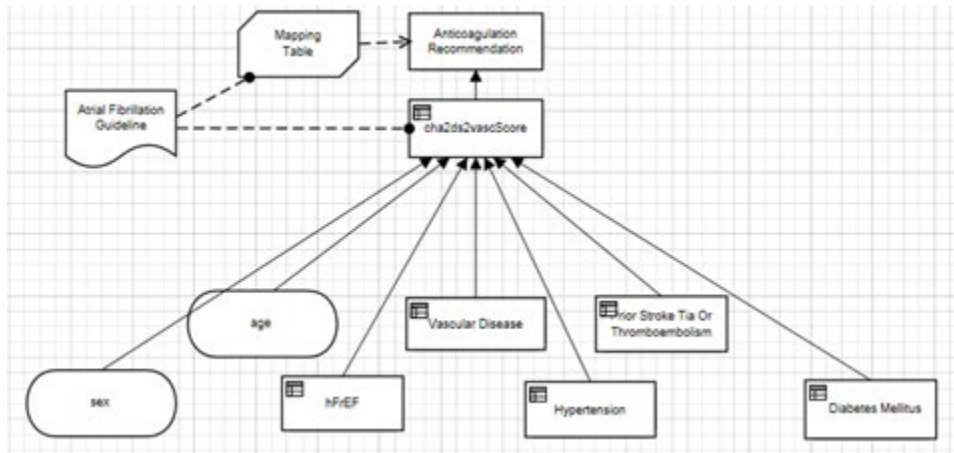


Figure 50 – Quantify – Recommend – CHADS2VASc

The Figure 50 above (Quantify - Recommend – CHADS2VASc) is an example of a scorecard that takes a number of inputs, assigns a number to each (e.g., +1 for hypertension), and sums the numbers to arrive at a score. The score is used as the basis for anticoagulation-therapy recommendations.

- ❖ Note that there can be an implicit interpretation; that is, each value of the score corresponds to a range of stroke risk. However, the actual numeric score is the input to the recommendation decision.

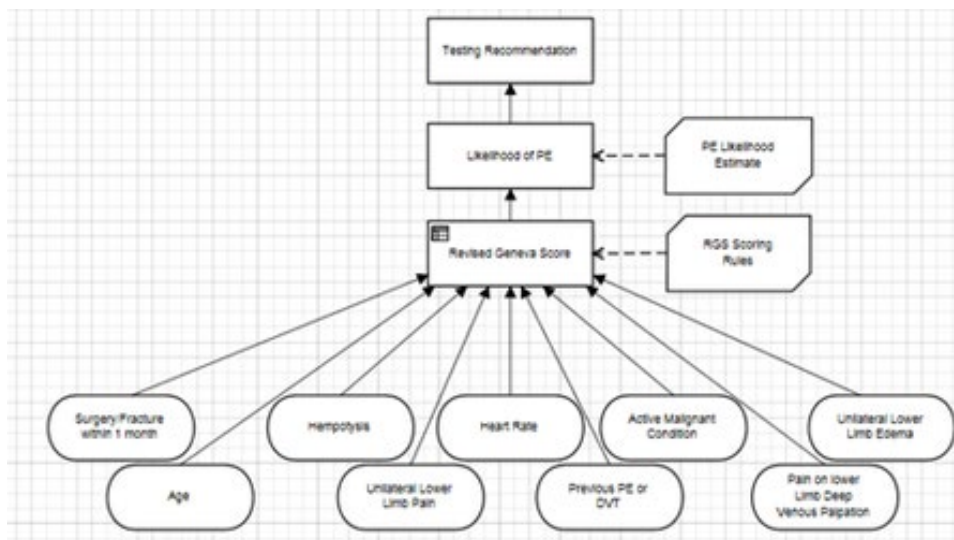


Figure 51 – Quantify – Interpret – Recommend: Pulmonary Embolism / Diagnostic Testing

The Figure 51 above (Quantify - Interpret – Recommend: Pulmonary Embolism / Diagnostic Testing) shows the Geneva Score (Revised). The purpose of the Geneva Score (Revised) is to determine the pre-test probability of pulmonary embolism. Its value is used to assign the patient to a low-, moderate-, or high-risk category. If the RGS is < 11, the patient is considered low to moderate risk; if the RGS is 11 or greater, the patient is considered high risk. The patient's risk category is then used to determine the next action. For low- to moderate-risk patients, a blood test (the D-Dimer) is used to further assess the probability of PE; for high-risk patients, an imaging exam is recommended as the next stage in the workup.

7.3. BPMN / DMN: Decision / Action

7.3.1. Description

In a medical business process model, decision logic is often used to direct process flow as "intent" and "recommendation" are executed by means of orders and, eventually, interventions. Process flow is often managed through (exclusive) gateways in a BPMN workflow diagram. This pattern mandates the separation between the "cognitive" aspects – modeled as Decisions that are embedded in a business process – and the proper "workflow" aspects, captured by the business process model.

7.3.2. Problem

The purpose of the (portion of the) pulmonary embolism guideline is to determine the best diagnostic option. As soon as this determination is made, and committed to, the analysis of the input data used in the RGS scoring algorithm can be considered complete. The next step is to execute, based on the outcome of that decision, so that a diagnosis can be reached. If the decision is to order the D-Dimer (justified by a RGS less than 11), then the workflow proceeds in one direction; if the decision is to order an imaging study (supported by a RGS greater than or equal to 11), then the workflow proceeds to a sub-process during which an imaging examination will be ordered.

7.3.3. Applicability

- Complex branching logic in a workflow gateway
- Logic can be encapsulated in a Decision

7.3.4. Pattern

The pattern uses a combination of BPMN – to capture the workflow and the temporal dependencies between the tasks – and DMN to model the actual decision logic. The logic is completely embedded in the decision tasks, and the gateways use simple patterns to express the branching logic based on the decision outcome. [Figure 52](#) depicts the generic form of this pattern as a workflow fragment.

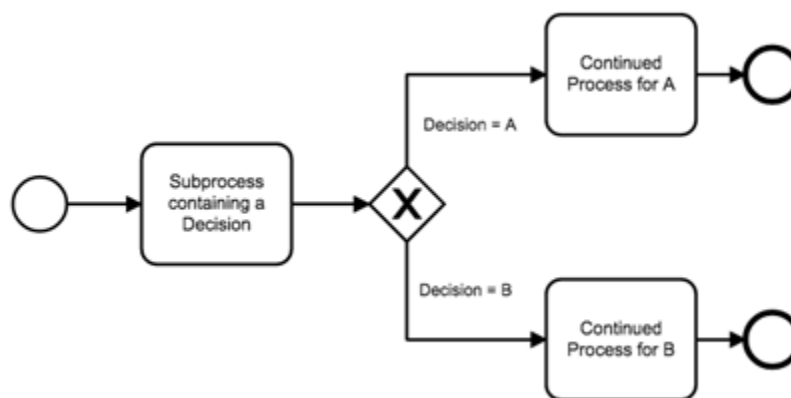


Figure 52 – BPMN diagram with exclusive gateway

The [Figure 52](#) above (BPMN diagram with exclusive gateway) illustrates a generic Business Process Modeling Notation diagram demonstrating the testing of a decision and an exclusive gateway to determine further

process flow. The sub-process leading to the gateway must contain the decision logic necessary to determine process flow at this gateway.

7.3.5. Specific Example

The Figure 53 below (pulmonary embolism workup decision) illustrates the process flow for the pulmonary embolism workup decision. A sub-process first collects and displays for review the data necessary to calculate the RGS. Then the process flow enters a decision model (see Figure 42, above, Interpretation of Score Decision Table). Emerging from the sub-process, the decision has been made, and the answer is used to determine which orders should be placed next. The actual modelling of the orders – and the subsequent interventions – varies and is covered by other patterns. In this example, ordering the D-Dimer is modelled as a simple task. Missing is the further workflow and decision-making necessary to choose which imaging modality to order in the alternative scenario.

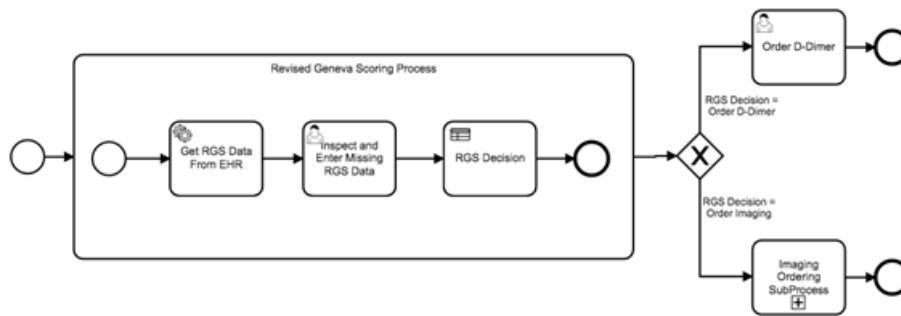


Figure 53 – Pulmonary Embolism Workup Decision

The Figure 53 above (pulmonary embolism workup decision) shows a sub-process that collects and processes the data necessary for the RGS Decision. Subsequently, this decision is used to choose between two process flows.

7.4. BPMN / DMN: Workflow-Interleaved Decisions Description

7.4.1. Problem

In general, decision models and (business) processes can be combined in complex ways. From a DMN perspective, dependencies between Decisions imply that a sub-decision may be used to better inform a parent decision. A business process can be used to orchestrate the temporal ordering between decisions, possibly interleaving them with tasks other than decision tasks.

It is important to remember that decisions can be made (i.e., DMN models can be evaluated) at any point in time. Until the decision outcome is committed to and actions are performed, one can further distinguish between actions that have no material consequence, actions that can be undone, actions that can be compensated, and ones that are irreversible. Factors to take into account are the actual cognitive/computational cost to evaluate a decision, and how relevant it is to (try to) make a decision at a certain point in time. Making an unnecessary decision may distract a clinician from taking active care of the patient and making an important decision at an untimely moment may require the decision to be revisited (e.g., when new information becomes available).

7.4.2. Applicability

- Multiple Decisions with mutual dependencies
- Workflow influences the timeliness of the Decision-making
- Workflow tasks gather/produce information required for decision making

7.4.3. Specific Example

In the full PE guideline, the RGS-based diagnostic choice is one of the early decisions. As data from labs and imaging is gathered, further testing may be required, ultimately leading to the decision on whether to treat or not. The interleaved Process (BPMN) and the Decision (DMN) components are shown in [Figure 54](#) and [Figure 55](#) below.

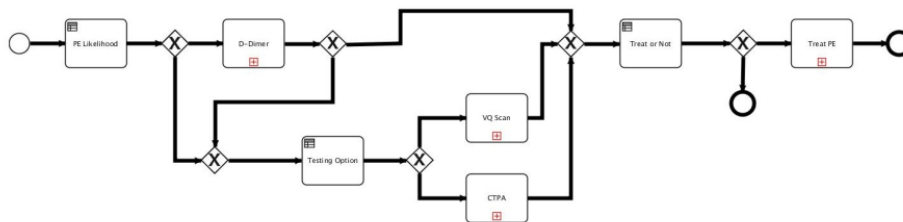


Figure 54 – Interleaved BPMN & Decision

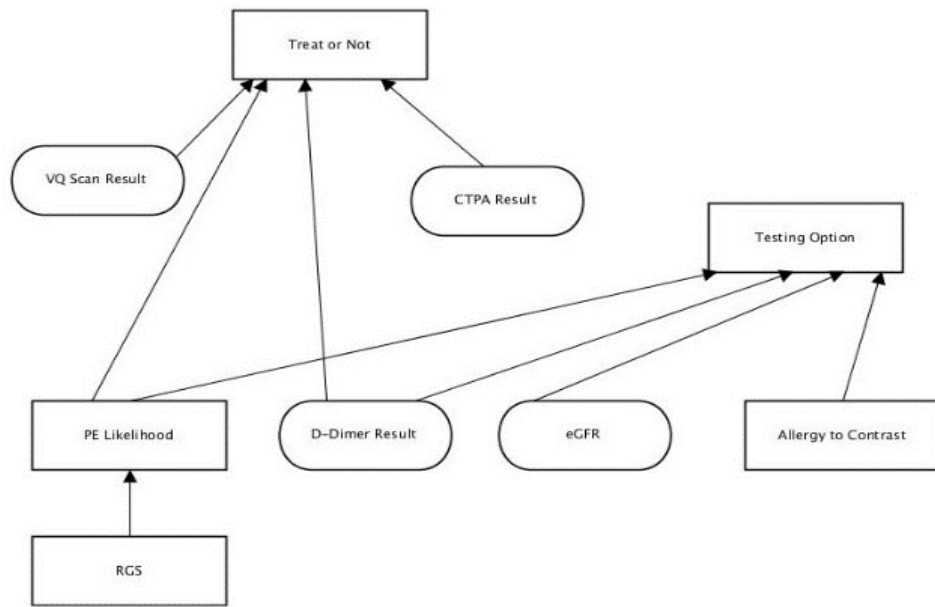


Figure 55 – Interleaved DRD

7.5. DMN: Team-based decision

7.5.1. Description

A team-based decision is a specialization of a multi-perspective decision. It involves multiple agents making the same decision, using individual -- but possibly overlapping -- decision criteria, decision logic, and knowledge sources. Eventually, consensus must be reached, and possible conflict must be resolved before a final determination can be made.

7.5.2. Problem

Complex decisions often involve reaching consensus among decision-makers who bring different perspectives to the same decision. In healthcare, many decisions are made collaboratively.

For example, determining the best treatment approach for a patient may require the input of experts from multiple disciplines. In cancer care, tumor boards may be convened to determine the best therapy for a patient. The board could include a radiation oncologist, a medical oncologist, and a surgeon as well as other specialists. Each agent takes into account the patient data for the case and the published evidence, but each brings different experience and tacit knowledge to the decision. The ultimate decision is made by consensus.

Another example of the team-based decision in healthcare is shared decision-making. Shared decision-making plays an important role in patient engagement. Patients who participate in decision-making are more likely to be compliant with the selected therapy. Patients and clinicians consider treatment options using multiple criteria that are ranked based on patient preference.

7.5.3. Applicability

This pattern applies under the following conditions:

- There are two or more distinct decision-makers trying to make the same decision in consultation with one another;
- All decision-makers have access to a common set of information. In addition, each decision-maker may have access to unique information and use unique decision logic; and
- The decision is reached collaboratively. There is only one conclusion.

7.5.4. Pattern

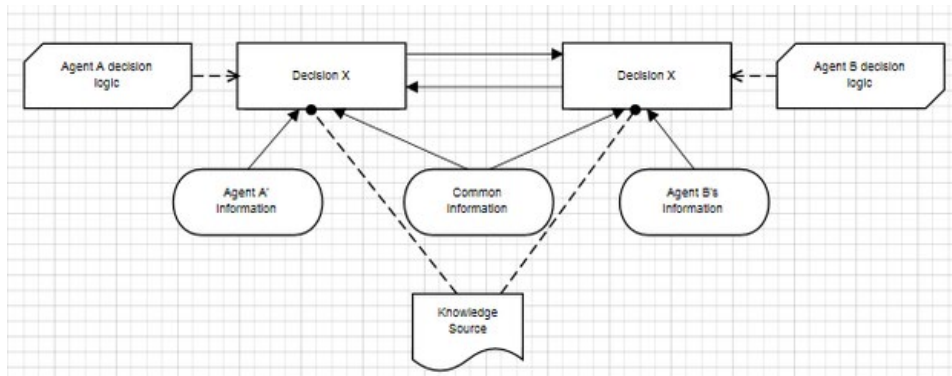


Figure 56 – DMN – Team-based decision pattern

Create two or more decision elements with the same questions and answers, one from the perspective of each decision-maker. The decisions share common data inputs and knowledge sources, but each decision may have additional inputs unique to that decision. Each decision-maker has unique decision logic, reflecting the different individualities.

Consider the individual knowledge sources that each decision-maker might require in making the decisions. If there are data inputs that not available to all decision-makers, model those data inputs separately.

In DMN, closed loops are not supported. A closed-loop system can either converge (reach consensus), oscillate indefinitely (each agent remains on their own position), or diverge (the team members part way) and cannot be modelled. To produce a valid DMN model, the loop should be replaced by an aggregating Decision, based on the same shared question/answer. This approach effectively replaces the need to reach consensus by calling out an explicit "referee."

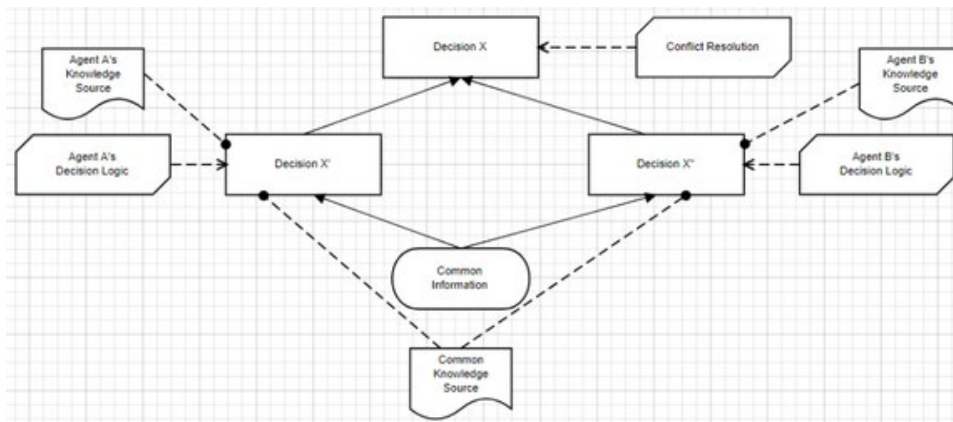


Figure 57 – Team-based decision Generic Example

7.5.5. Specific Example

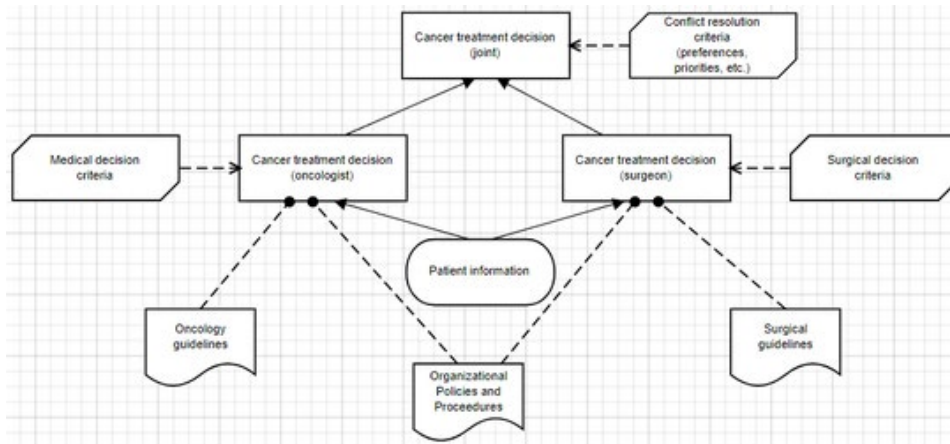


Figure 58 – Team-based decision specific example

In this example, an oncologist and a surgeon work together to reach consensus on the best treatment approach for a patient. Each makes a decision based on shared patient information, using different criteria and under the authority of different knowledge resources. They confer and reach consensus on optimal approach based on the individual perspectives.

7.6. DMN: Computer-aided decision support (CDS)

7.6.1. Description

A CDS pattern is a specialization of the multi-perspective pattern. It is used to model a (clinical) decision made by a human agent that is informed by a decision made by a computer. The computer decision aids the human by making the decision and proposing a recommendation.

7.6.2. Problem

Distributed cognition is common in knowledge work. Human decisions are often aided by computerized decision algorithms. The computer decisions may be overridden when the human agent takes into account inputs that are not available to or used by the computer.

In healthcare, clinical decision support (CDS) systems present alerts, reminders, and recommendations to clinicians at the point of care to enforce desired behaviors or prevent errors and omissions. For example, there are well-accepted guidelines on prescribing anticoagulation therapy for patients with atrial fibrillation that take into account a patient's likelihood of stroke (CHA₂DS₂-VASc) and likelihood of major bleeding (HAS-BLED). CDS systems can calculate these scores and make a recommendation on whether to prescribe anticoagulation treatments. The clinician takes that recommendation into account, along with other inputs (including data found and also not found in the patient's record as well as data contained in the patient's record but not used in the logic of the CDS rule), to make the decision whether to prescribe an anticoagulant.

7.6.3. Applicability

This pattern applies under the following conditions:

- There are two distinct decision-makers trying to make the same decision: The human and the computer system;

- Both decision-makers base their decisions on the same premises to the degree possible. (data, information, and knowledge); and
- The human is the decision-maker who is ultimately responsible and accountable for the decision.

7.6.4. Pattern

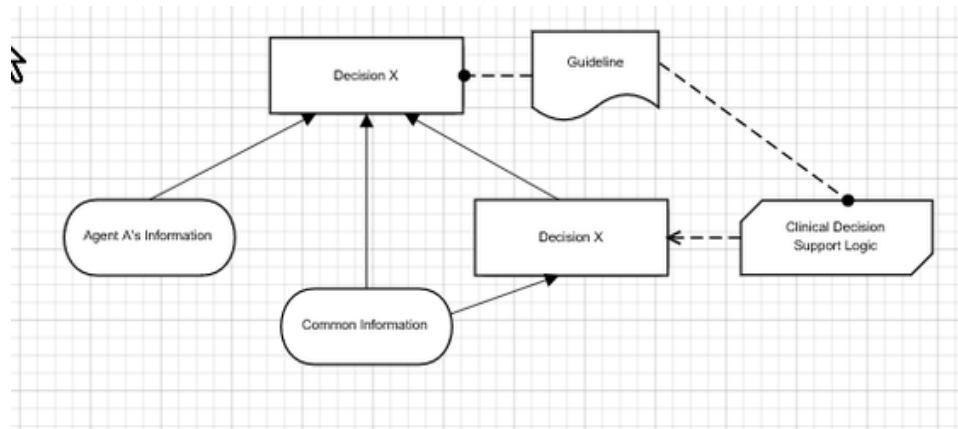


Figure 59 – DMN: Computer-aided decision support (CDS)

Create two decision elements with the same questions and answers: one with the human (clinician) decision-maker and one with the computer (CDS) as decision-maker. The decision made by the CDS system informs, and thus is a sub-decision of, the clinician's decision. The same knowledge source should inform both the CDS decision and the clinician's decision. The actual logic used by the CDS system is computable by definition and should be modeled explicitly using the business knowledge model (BKM) element.

Knowledge sources include evidence-based guidelines, policies, etc. If a local adaptation of a more general guideline exists, the local version should be used. Best practice is to use the actual authority that was used as the basis for the CDS rule.

The BKM can either embed the logic if the decision model is intended for computation or can reference some external location where the logic is available in a computable format. This mechanism could allow a direct connection between the decision model and the organization's CDS rules library and insulates the overall model from changes to the CDS system.

It is assumed that the clinician has access to all of the data elements (usually from the electronic health record or similar sources) that the CDS system uses. These data elements are modeled as input data shared by both decisions. The converse is usually not true; the clinician may have access to other information that is not available to or used by the CDS system.

7.6.5. Specific Example

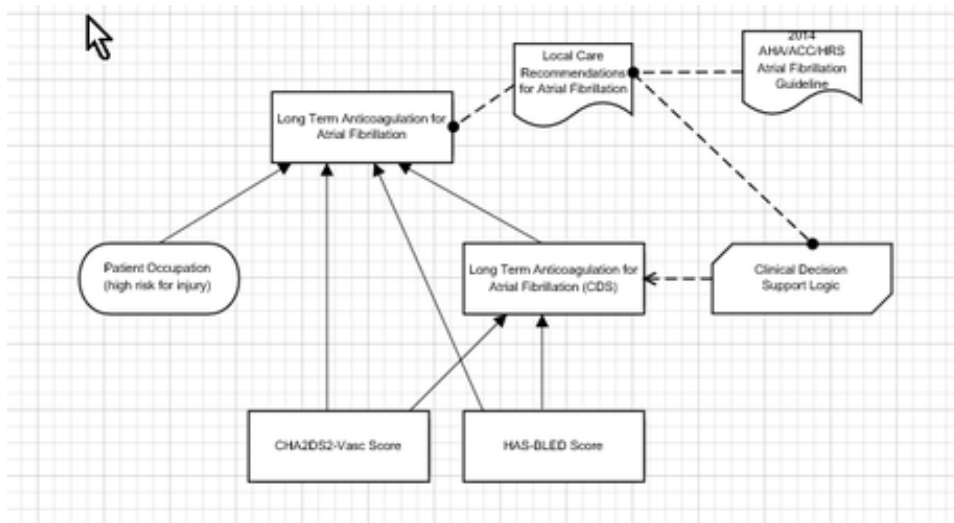


Figure 60 – DMN: Computer-aided decision support (CDS) Specific

The example illustrates the long-term anticoagulation decision described above. In this case, the CDS system calculates the CHA2DS2-Vasc score and the Has-Bled score and on the basis of those scores, recommends long-term anticoagulation.

In some scenarios, the CDS system will recommend anticoagulation. The clinician will consider the recommendation and also the patient's occupation. Should their job put the patient at high risk for injury, the clinician may decide not to initiate anticoagulation.

7.7. DMN: Multi-perspective (Treatment) Decision

7.7.1. Description

The treatment decision pattern is a complex pattern that incorporates multiple sub-patterns. The goal is to capture an abstract decision on how to treat a patient, looking at the problem from the different perspectives of different agents.

This pattern is an extension of the Team-based Decision pattern, where multiple agents try to make the same decision from similar perspectives. In this pattern, each agent also makes the same decision from multiple perspectives.

7.7.2. Problem

Determining the optimal treatment for a patient involves multiple agents making multiple sub-decisions that feed into the ultimate therapeutic decision. A clinician may consider the decision from a population perspective (what is the best treatment for patients like this one, based on population studies?), from the medical perspective for the individual patients (what is the optimal treatment for this patient, given demographic factors and comorbidities?), and from the socioeconomic perspective (what is the optimal treatment for this patient given the socioeconomic context?).

Eventually, clinician and patient collaboratively make the final decision.

7.7.3. Applicability

- This is the same as a Team-based decision.
- A decision can be made from different perspectives $P_1, .. P_n$
 - Given a fixed set of inputs, the outcome of the decision from perspective P_j is possibly different than the outcome of the same decision from perspective P_k

7.7.4. Pattern

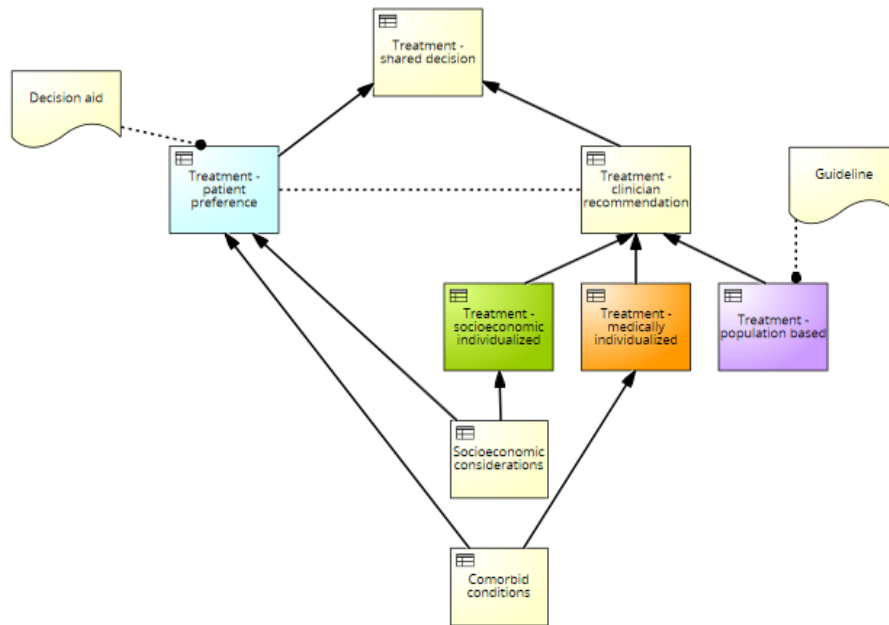


Figure 61 – Multi-perspective (Treatment) Decision Pattern

Model the top-level treatment decision with two sub-decisions with the same question and possible answers: one with the patient as the decision-maker, the other with the clinician as the decision-maker. The clinician's treatment decision, in turn, has three sub-decisions made from multiple perspectives: The population-based decision which considers the evidence-based guideline; the medically individualized decision, which considers patient-specific factors (e.g., comorbidities); and the socioeconomically individualized decision, which incorporates factors such as support systems, cultural considerations, and financial capacity.

- ❖ *Note that other patterns may apply. For example, the population-based treatment decision may be informed by a CDS intervention that, in turn, provides some sort of recommendation based on a quantitative scoring model.*

7.7.5. Specific Example

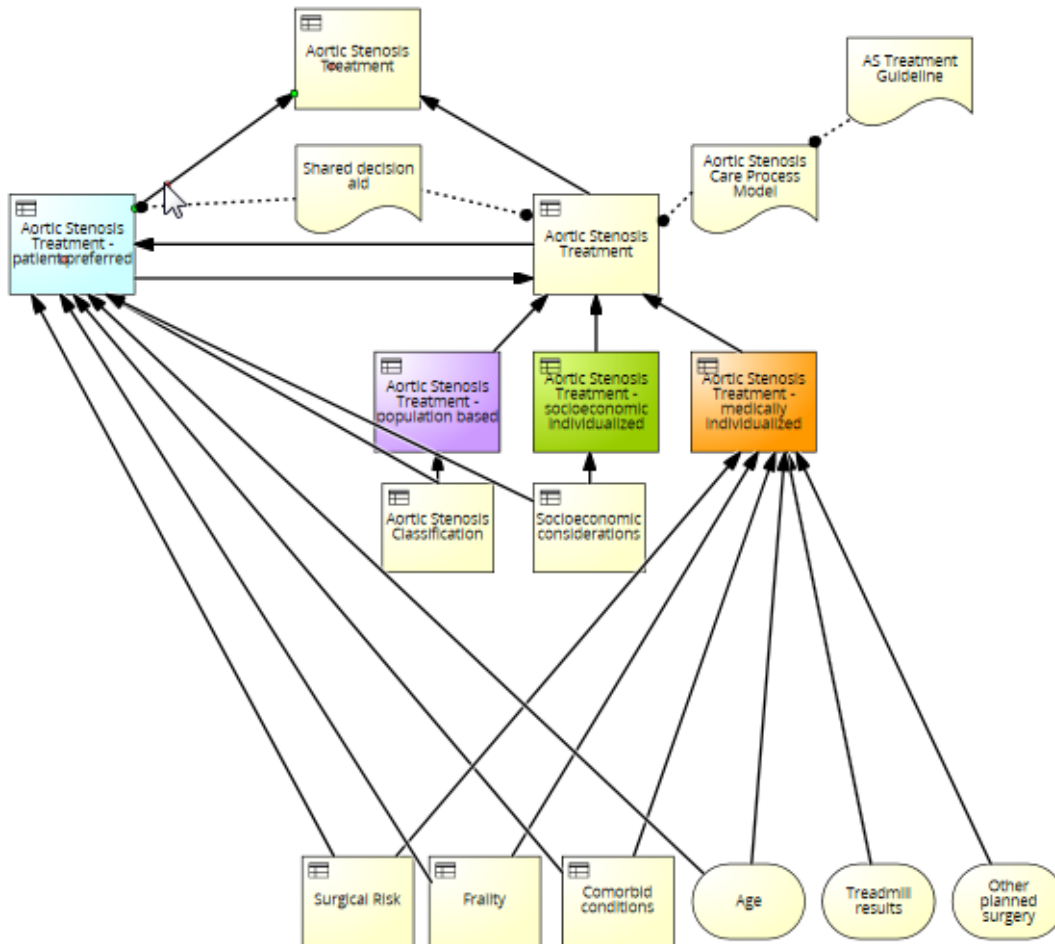


Figure 62 – Multi-perspective (Treatment) Decision Pattern

7.8. DMN: Team-based decision

7.8.1. Description

Clinicians often make "chains" of decisions: complex cognitive processes such that the output of each decision informs the next decision and also what decisions to make next. The chain is implicitly aimed to optimize the cognitive load, so that attention is only focused on what matters, when it matters, and if – and only if – it matters.

For example, a guideline for the treatment of atrial fibrillation may recommend putting a patient on a long-term anticoagulant regime. A physician will eventually have to place an order, which requires a level of detail regarding the actual drug and (among other things) its form, dose and schedule. Way before then, however, the physician will determine whether the patient is an actual candidate for anticoagulation and only then what kind of anticoagulant to administer (e.g., warfarin vs. oral anticoagulant).

7.8.2. Problem

Even if decision models can be refactored without altering the overall semantics, some formulations can be more efficient than others. Part of what is called "expertise" is being able to optimize cognitive processes. In a decision model, this can be reflected by virtue of identifying, and properly separating, the decisions that deal with the problem at hand from those decisions that guide the cognitive process.

The optimal cognitive process can then be represented explicitly in a variety of ways. We propose two alternative representations: one based on BPMN and one based on CMMN. In this sense, this pattern specializes the Workflow-Interleaved Decision one.

A BPMN model, prescriptive by nature, can be used to specify the optimal, "natural" flow of decisions. In this model, each decision should be made, and made at a specific point in time (at least relatively to the other decisions).

In a CMMN model, adaptive by nature, the "control" decision determines the applicability (at planning time when the case is opened) and/or the eligibility (reactively, during the execution of the case) of other decisions.

7.8.3. Applicability

- A complex decision problem can be decomposed into a tree of Decisions
- Intermediary decisions influence what decision to make next

7.8.4. Specific Example

In the anticoagulation scenario, the clinician tries to determine as soon as possible whether the patient is eligible for anticoagulation. If that is not the case, no more effort will be invested in further trying to determine the details of an anticoagulation therapy that will never be prescribed. In this sense, this first decision is an "applicability decision."

The second decision, a "choice decision," resolves some of the degrees of freedom of the problem (i.e., which anticoagulant to use), but not all (e.g., the dose and schedule). In fact, it does not make sense to even frame the problem of dosing the drug until the choice of which drug has been made.

The BPMN representation of this process used branching logic (gateways with guards) to orchestrate the decisions. Notice that the applicability decision is Boolean (true/false), while the choice decision is categorical. With this model, only the relevant decisions are made – i.e., only the meaningful information is processes – and only at right point in time.

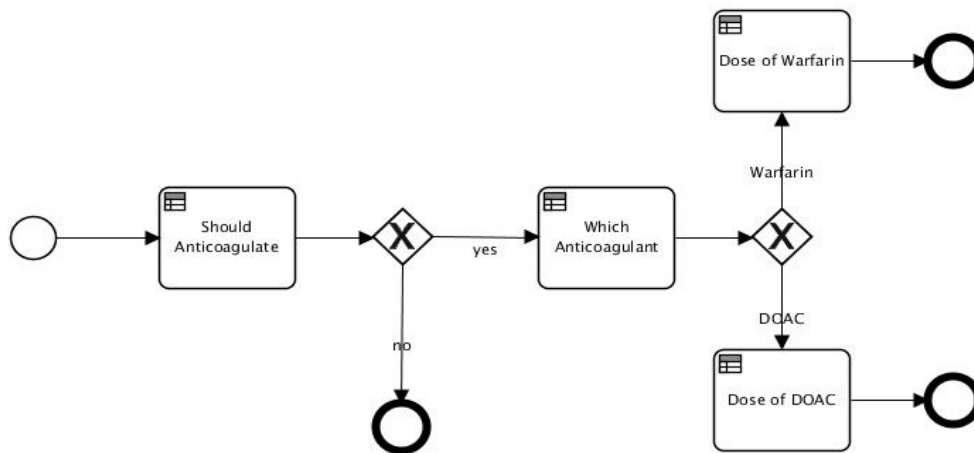


Figure 63 – DMN: Team-based BPMN decision

The CMMN formulation is analogous but has some important differences. The initial applicability decision serves to determine whether the entire anticoagulation stage shall be part of an individual case or not. If so, the choice of which anticoagulant is deferred to the proper time, as triggered by an event. Because the patient is eligible for anticoagulation, the type of anticoagulant must be chosen at some point before closing the case.

If and when an anticoagulant is chosen, depending on the choice, it is possible to make an appropriate decision regarding the actual dose.

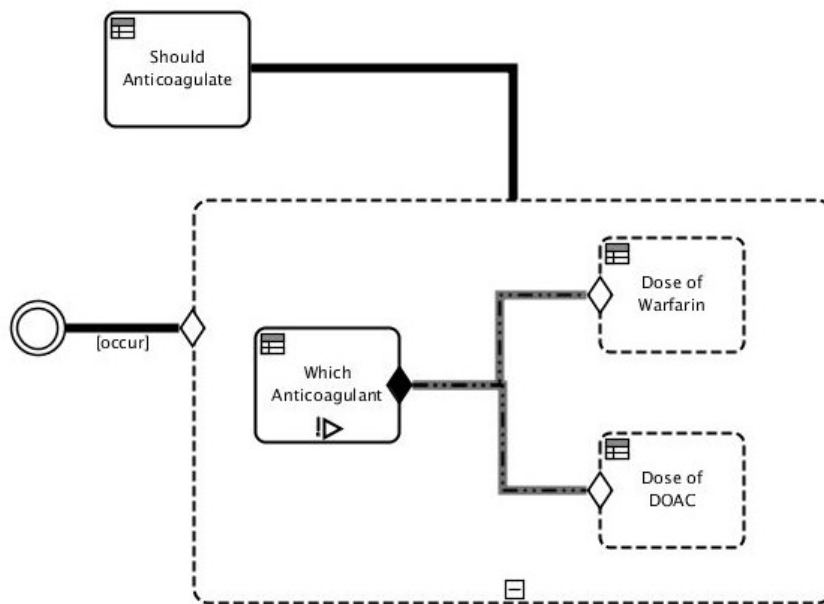


Figure 64 – DMN: Team-based CMMN decision

8. Appendix C – Sustainment and Governance

Whether developing process models for use within your own institution or as a contributor/consumer part of a broader ecosystem, the role of governance and model management within the environment in which you work will have direct impacts on how models are created and also how they are tagged, versioned, and managed. This section will make allusions to the formalities of model management within an ecosystem – internal or community-based – but it is not intended to document all of the governance required to support the full model management lifecycle. There are more extensive resources better suited to that need.

Instead, this section will attempt to highlight the importance of the broader context of model management to the individual consumer or contributor, rationalizing why those steps are important and calling out key elements for consideration as part of your modeling activities.

8.1. Governance Goals

Process models are not created in a vacuum: They rely heavily on industry best practices; internal institutional approaches and workflows; relationships to other activities; constraints, such as performance and quality measures; and so on. Moreover, when documenting models, we are often extending or adapting other work, creating new derivatives or variants on something in place today, whether that was invented locally or adapted from elsewhere.

Governance activities exist to maintain confidence and integrity of the models being produced and consumed. This typically includes activity steps to assure that the artifacts contributed are accurate, documented, fit-for-purpose, and managed with integrity. The extent of rigor and formality associated with governance processes typically relates to the organizational size and complexity, the volume of assets being governed, the number of stakeholders involved in the activities, and the clarity of ownership around the content.

As you create and consume models, please bear the following in mind:

For INTRA-INSTITUTIONAL efforts:

1. Governance is typically defined by policy;
2. Specificity around the description of artifacts may or may not be rigorous, depending upon the strength of the vernacular within the organization, its size, and institutional variability (or lack thereof); and
3. Stakeholders may be defined by specific job titles, roles, or even individuals' names.

For ECOSYSTEM/EXTERNAL efforts:

1. There may be contribution policies affecting the ability to post models. These may be quality constraints of the ecosystem itself, or institutional policies affecting what can be contributed;
2. Management of intellectual property is of paramount importance (e.g., requiring certain distribution licensing, articulating IP constraints and compatibilities, limitations on use or derivative use, and so on);
3. Management of versioning, interdependencies among contributions, and a taxonomy of contributed content is key to asset management;
4. Use of common expression languages (such as BPMN/CMMN/DMN); and
5. Sustainment and enforcement of identifying metadata to allow for the effective contribution, discovery, and consumption of community assets

It merits mention that the care taken as part of the asset curation processes (e.g., versioning, metadata tagging, quality management and oversight processes, and so on) will have huge implications in terms of how effective the model repository can be, and ultimately in the efficacy of the models and their usage. When high-quality models are produced and contributed into a repository lacking these controls, it is left to the consumer to download, assess, make a determination, and ultimately utilize that content. This puts a significant burden on the consumer, eroding confidence in the content and ultimately jeopardizing the efficacy of the contribution.

Well-curated environments instill confidence, facilitating accurate discovery of relevant content, demonstrating pedigree and relationship among assets, and fostering effective use of relevant contributions. *For the individual contributor and consumer, spending the time to appropriately tag new submissions, to relate content to other community assets, to evaluate community assets based on their efficacy and relevancy, and to participate within the ecosystem is of paramount importance.*

8.2. Content Management

The following are high-level recommendations with respect to curating and describing process models that are produced with the intention of sharing. The key differentiator between internal and community consumption lies in the ability to express and describe context, which becomes particularly relevant when content is intended for out-of-organization consumption.

Model Curation. Establishment of a common set of metadata to describe process models helps facilitate their storage and discovery at point-of-use. See [Figure 65](#) for the core set of metadata recommended for contributed assets.

❖ *Note that this set was derived from existing asset repositories and based upon the experiences of BPM Health Pilot activities.*

Identification and Versioning	
	Name/Title
	Asset Id
	Version Number
	Description
Representation	
	Language
	Notation
	Used Vocabularies
Provenance/Pedigree	
	Author
	Contributing Organization
	Sources/Bibliography

Distribution	
	Implementation Considerations
	Distribution License / IP Mode
	Target Audience/Setting

Figure 65 – Asset Metadata Set

8.3. Asset Management

Metadata such as the above are often realized as tags on asset contributions into an asset-management system. This can be something as simple as an internal configuration-management tool or may be as complex as an industry repository or hosted capability. For the purposes of this discussion, we will assume that a shared asset repository is the target environment, and that the tool supports a broad community of participants from across multiple institutions.

In this type of setting, typically there are managed contribution processes, where individual contributors are able to upload assets and tag those assets based upon a set of style guidelines. Following the original contribution, there are varying approaches to content curation. These may be done actively, where only curated content is available to the community following upload and vetting. Alternatively, some marketplaces take a more passive role, allowing for community-based ratings and review, but not proactively managing on behalf of the ecosystem.

As a contributor, it is important to understand the implications of the target environment, and the responsibilities prior to the submission process. Are you required to support your submission? Are there intellectual property requirements or constraints? Are there distribution constraints of your contribution, and can those be supported by the tooling? Are there certification steps required of the contribution? It is questions like these that will influence which communities are best suited to your work, and whether your intended consumer audience is participating in the environment you have selected.

8.4. Choosing an Ecosystem

Given that this Field Guide is principally around process modeling best-practices to allow for process portability and sharing, the selection of the ecosystem to host that sharing is an important consideration. Why? Because the policies of the ecosystem, the stakeholders participating, the tooling underpinning it, and the governance within it will ultimately determine whether model sharing can be effectively realized, and whether your contributions or consumption will be effective and viable.

Ultimately, an ecosystem is about establishing symbiotic relationships among organizations, allowing for the discovery of usable assets and providing a channel for the effective sharing of others. The following is not intended to be an exhaustive list; rather, it is the expression of several key dimensions to consider when choosing where and how to share:

- **Ecosystem Legitimacy:** Is this a community of the "right" organizations? Do they have institutional credibility? Are they trusted within the industry? Do we have confidence in their objectives and policies? Are we comfortable working with them?

- **Community Meritocracy:** Are contributions within the community based upon their efficacy and quality? Is the infrastructure in place to allow the ecosystem to decide what is good or not good? Do any institutions hold undue influence or sway, potentially to the adverse benefit of the community?
- **Openness and Transparency:** Are policies in place to allow for the discovery of activities underway, and/or the ability to create new or competing activities? Are governance rules clearly articulated and consistently applied to all community members? Does the community favor a specific vendor or is it a "level playing field?"
- **Governance:** Are rules associated with contributions, quality management, asset management, and distribution clearly articulated and consistently enforced? Are oversight activities and bodies open to all participants, either directly or in a representational fashion (e.g., elected members)? Are governance rules objective and evidence-based?
- **Tooling:** Are tools being made available to the membership and consuming community? Are the tools home-grown or commercially available? Is the tooling environment or infrastructure open, and/or does it allow for effective inter-operation with your institutional needs?
- **Business Model Compatibility:** Does the ecosystem align or complement with your institutional needs in terms of business and/or revenue model? (e.g., some ecosystems serve as a distribution/licensing model, such as the Apple App Store). Does the ecosystem support/enforce your asset distribution requirements? Is the ecosystem sustainable?

The selection of an ecosystem has tremendous impact on the viability and efficacy of model sharing. Ideally, your selected channel will meet all of the above requirements but, in reality, different communities will have inherent strengths and weaknesses. An honest assessment of the above – taking into account risks and organizational needs – will help you to make well-informed decisions.

9. Appendix D – Glossary of Terms

Activity – An Activity is the term for the work that a company performs in a Process. An Activity can be atomic or non-atomic (compound).

BPM+ – This is a short-cut term that refers to the set of OMG standards used in Shareable Clinical Pathways (Knowledge Models): BPMN, CMMN, and DMN. New OMG standards may be added to this list as they are developed, including standards for packaging Knowledge Models (KPMN) and Situational Data Models (SDMN).

Business Process Modeling and Notation (BPMN) – BPMN is an approved OMG specification. The BPMN specification provides a graphical notation for specifying business processes. See <http://www.omg.org/bpmn/index.html> for more information about BPMN and its specification.

Case Management Model and Notation (CMMN) – CMMN is an approved OMG specification that is compatible with, and complementary to, the OMG BPMN specification and the OMG DMN specification. CMMN defines a common meta-model and graphical notations for expressing a model developed using the CMMN Standard. A Case is a proceeding involving the care of a patient or a healthcare business transaction to achieve a desired outcome. CMMN provides concepts to Business Process Models by adding such concepts as Roles and Activity Listeners. See <http://www.omg.org/spec/CMMN/1.1/> for the complete CMMN specification.

Choreography – Within BPMN, Choreography defines the way business participants coordinate their interactions and exchange of information among involved parties. The coordination of interaction is defined by how each party interacts with its counterpart; there is no central orchestration or control.

Clinical Pathways – Clinical Pathways are workflow definitions that outline the necessary steps and goals in the care of patients under a set of defined conditions. Clinical Pathways can be fully described using a combination of BPMN, CMMN, and DMN Notations.

Clinical Decision System (CDS) – Clinical Decision Systems encompasses a variety of tools to improve outcomes, generally at the point of care.

Data Object – Data Objects provide information about what Activities require to be performed and/or what they produce. There are two types of Data Objects: Data Input and Data Output.

Decision Modeling Notation (DMN) – DMN is an approved OMG specification that is compatible with, and complementary to, the OMG BPMN specification and the OMG CMMN specification. DMN provides a meta-model and a graphic notation to document decisions events found in processes. The DMN notation is designed to be useable alongside the standard BPMN business process notation. See <http://www.omg.org/spec/DMN/1.1/> for the complete DMN specification.

Decision Requirements Diagram (DRD) – A DRD is the DMN diagram for displaying Decisions, Decision Services, Data Inputs and other DMN elements.

EHR – EHR refers to an Electronic Healthcare Record system used to capture and store healthcare information. Electronic Medical Record (EMR) systems are synonymous with EHR systems.

FHIR^(R) (Fast Healthcare Interoperability Resources^(R)) – FHIR is a standard for exchanging healthcare information electronically (taken from FHIR page). See www.hl7.org/fhir for more information.

HSSP (Healthcare Services Specification Platform) – HSSP is a joint initiative of the OMG and the Health Level 7 standards organizations. The objective of the HSSP project is to create useful, usable healthcare standards that define functions, semantics, and technology bindings supportive of system-level interoperability for the

healthcare industry. See https://en.wikipedia.org/wiki/Healthcare_Services_Specification_Project for more information.

HSPC (Healthcare Services Platform Consortium) – HSPC is a provider-led and vendor-involved consortium dedicated to establishing a scalable, truly interoperable data and services architecture for healthcare. See www.hspconsortium.org for more information.

HL7 (Health Level Seven International) – The ANSI-accredited standards-developing organization dedicated to providing a comprehensive framework and related standards for the exchange, integration, sharing, and retrieval of electronic health information that supports clinical practice and the management, delivery and evaluation of health services.

IHE (Integrating the Healthcare Environment) – A non-profit organization who sponsors initiatives by which the healthcare industry can improve the way computer systems share information.

OMG (Object Management Group) – The Object Management Group® (OMG®) is an international, open-membership, not-for-profit technology standards consortium. OMG standards are driven by vendors, end-users, academic institutions, and government agencies. OMG Task Forces develop enterprise-integration standards for a wide range of technologies and an even wider range of industries. The Healthcare Domain Task Force is the working group for the healthcare industry within the OMG. See www.omg.org for more information about the OMG.

10. Appendix E – Hello Patient Models

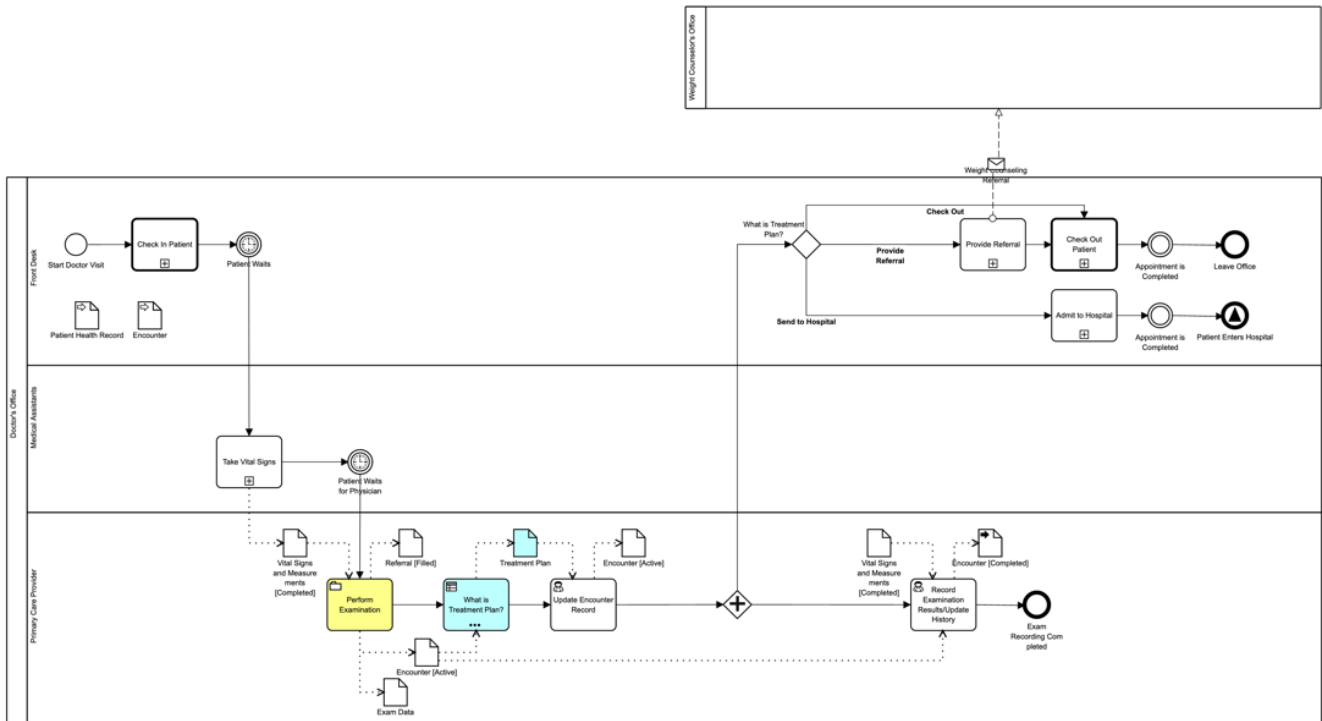


Figure 66 – Hello Patient BPMN Main Process

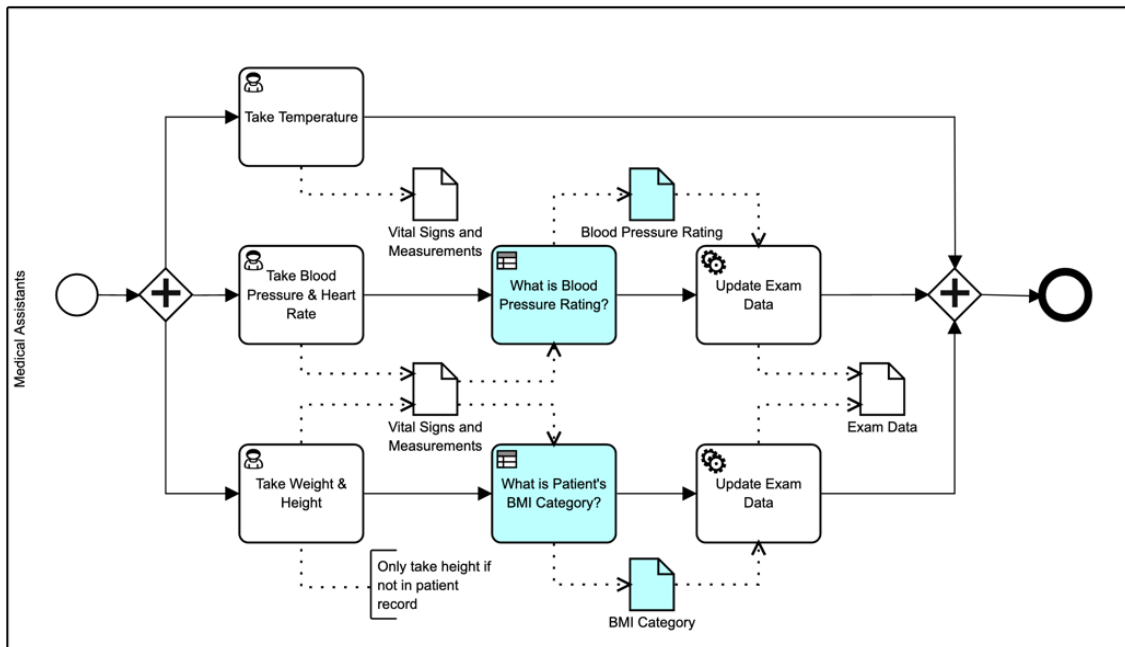


Figure 67 – Hello Patient BPMN Take Vital Signs Process

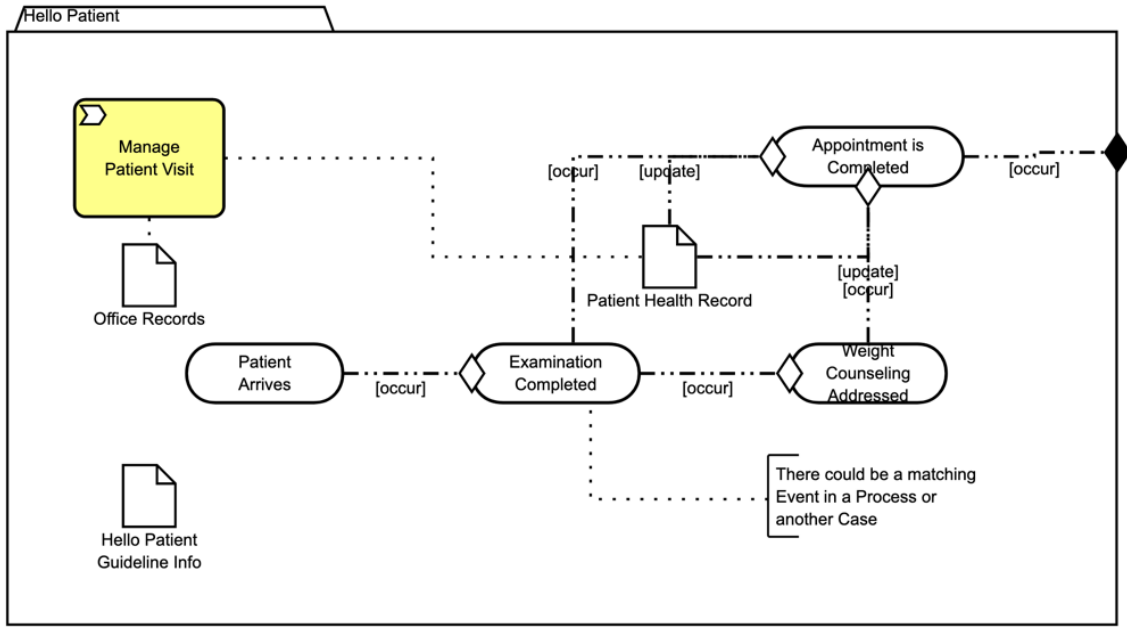


Figure 68 – Hello Patient CMMN Main Case

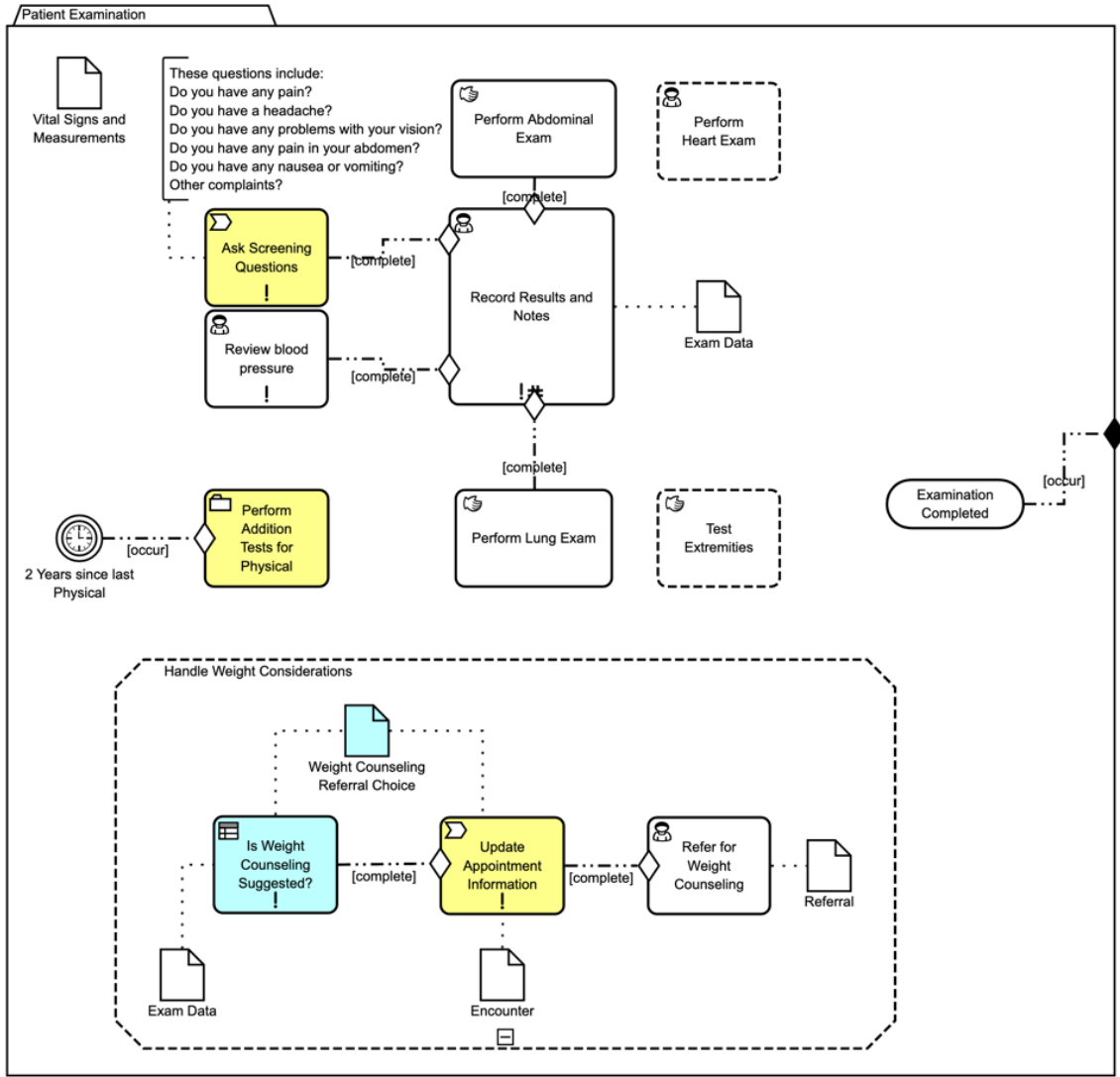


Figure 69 – Hello Patient CMMN Examine Patient Case

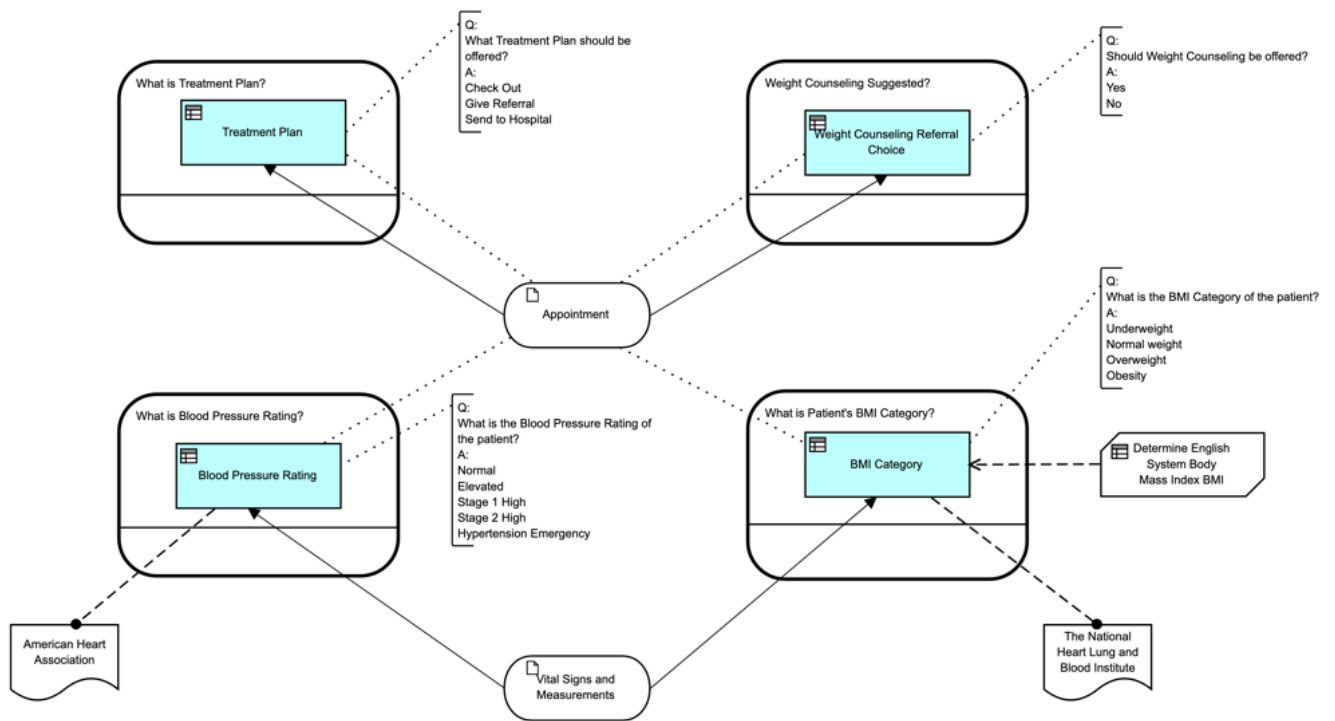


Figure 70 – Hello Patient DMN Decision Services

11. Suggested Readings

Title	Author
BPMN Quick and Easy using Method and Style	Bruce Silver
BPMN Method and Style, 2nd Edition	Bruce Silver
DMN Method and Style	Bruce Silver
Real-World Decision Modeling with DMN	James Taylor and Jan Purchase

12. Future Work

Future versions of the BPM+ Health Field Guide will include or expand on the following topics:

- Common Patterns in healthcare, including:
 - Observations and Findings
 - Order Sets
 - Questionnaires and Documentation Templates
 - Quality Measures
 - Comorbidities
- Expanded definition of Shareable Clinical Pathways, including
 - Knowledge Package Models
 - Including the Knowledge Package Manifest
 - More detailed metadata
 - Situational Data Models
 - Descriptive Narratives and other supporting resources