

BPMN Model for the Unstable Angina Pathway of a Dutch teaching hospital[☆]

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1. Extended Results Description

The case study conducted at the Catharina Hospital towards the Care Pathway of Unstable Angina resulted in (1) an organization chart of the involved stakeholders (see Figure 1) and (2) a business process model of 26 diagrams consisting of five granularities (see Table 1 and Table 2) which covers the entire hospitalization period resulting from an admission because of acute chest pain. Note that there are differences in the level of detail between diagrams, due to usage of (collapsed) sub processes (see Appendix AppendixA for a short explanation about the used BPMN 2.0 constructs). Here a brief explanation of the top-level model and the overview of the five phases will be given.

1.1. Top-Level Model

The Top-Level diagram, called *CP UA @ CHE* (see Figure 2), gives an overview of the entire care process from arrival to departure according to five phases that are aligned with the clinical guidelines [2]. An overview of the involved departments and units per phase is given in Table 3. The model contains options to filter all non-standard UA/NSTEMI patients from the pathway, as all non STEMI patients with chest pain arriving at the hospital start within this path. Non-standard patients are withdrawn from the pathway by one of the three included ‘escape’ options, represented in the model by (intermediate) errors event;

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Table 1: Overview of the coherency between the different model diagrams

Diagram	Granularity			
	Level (1)	Level (1a)	Level (2)	Level (3)
	CP UA @ CHE			
Diagram	CP UA @ CHE		Initial Evaluation	- Give nitrates
			Diagnosis validation and risk assessment	- Take ECG - Give medicine (ACS-NSTEMI) - CK/CKmb measuring
			Invasive Strategy	- Give medicine (ACS-NSTEMI) - Take ECG - Perform CAG
		Revascularization modalities	Prepare and conduct PCI	
			Pepeare, await and hold Heartteam meeting	- Give medicine (ACS-NSTEMI) - Take ECG
			Await and conduct screening + intake CABG	- Screening + intake CABG - Give medicine (ACS-NSTEMI) - Take ECG
			Await CABG	- Give medicine (ACS-NSTEMI-CABG)
			Prepare acute CABG	
			Perform CABG	
		Hospital discharge	Nurse and mobilize patient (at Cardio)	- Give medicine (ACS-NSTEMI) - Take ECG
			Discharge patient (at Cardio)	- Take ECG
			Provide post operative care	- Give medicine (ACS-NSTEMI-postCABG) - Take ECG @ IC
			Nurse and mobilize patient (at CTC)	- Give medicine (ACS-NSTEMI-CABG)
			Discharge patient (at CTC)	

Figure 1: Organization view of the Catharina Hospital Eindhoven

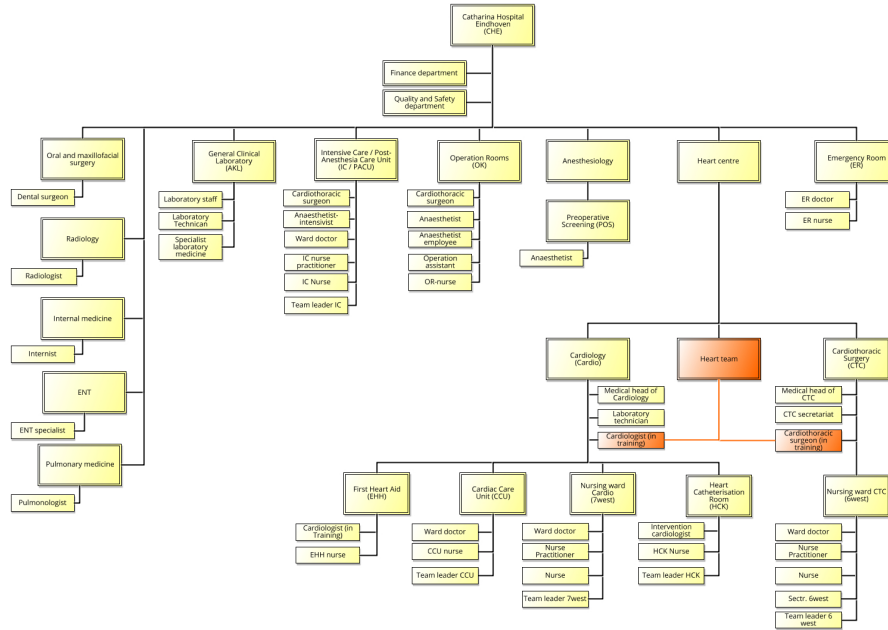
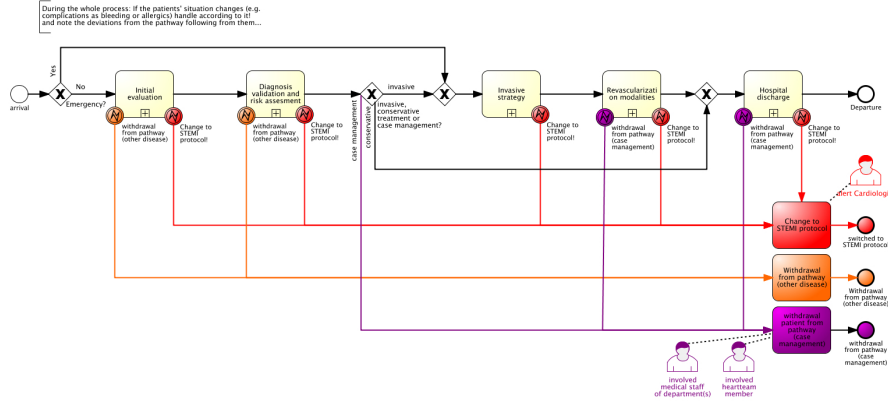


Table 2: Overview of the granularity levels of the Care Pathway model for Unstable Angina

Granularity	Description
Level (1)	Top-level, providing the overview of the different phases of the Care Pathway.
Level (1a)	Overview of the phase. <i>Only applied in the phases Revascularization modalities and Hospital Discharge.</i>
Level (2)	Process within the phase, containing collapsed and expanded sub processes for tasks executed by the same role and belonging together (e.g., "take blood test" and "take ECG").
Level (3)	View of the sub processes with for medication either; (1) the pharmacological or chemical subgroup of medicine as this is explicitly mentioned in the clinical guidelines (e.g., Aspirin and P2Y12 inhibitors) or (2) the name of the chemical substance of medicine (e.g., paracetamol and lorazepam).
Level (4)	Tasks for medication with either; (1) the name of the chemical substance of medicine (e.g., ASA en Ticagrelor) or (2) the dose that needs to be given.
Level (5)	Tasks for medication with for (1) the dose that needs to be given.

Figure 2: Top-level of the Care Pathway for Unstable Angina model



21 **Change to STEMI protocol!:** In case an Electrocardiogram (ECG) confirms
 22 STEMI, the patient needs to be switched to the STEMI protocol immedi-
 23 ately. A Cardiologist will be alerted and the patient will leave the pathway
 24 at the top-level through the corresponding error end event.

25 **Withdrawal from pathway (other disease):** In case the Cardiologist
 26 concludes that the chest pain is not resulting from ACS, the patient is with-
 27 drawn from the pathway by throwing the corresponding error.

28 **Withdrawal patient from the pathway (case management):** If a patient
 29 has UA and can no longer follow the Care Pathway (e.g., due to serious
 30 complications or comorbidities) case management needs to be applied. At
 31 the top-level, the involved medical professionals are triggered to make a
 32 personal treatment plan for this patient in order to withdrawal.

33 The care process starts at the top-level with the *arrival* of a referred patient with
 34 chest pain at the hospital's EHH department or in case of *emergency* is directly
 35 sent to the HCK for the *Invasive strategy*. The distinction between emergency
 36 and non-emergency patients is made before the model starts. Most patients
 37 with UA arrive at the EHH and start with the *Initial evaluation* followed by the
 38 *diagnosis validation and risk assessment*, in which they will be assigned to one
 39 of the three treatment plans. The first option is a *conservative* treatment; the
 40 patient will receive a drug therapy and continues the care process within the
 41 *Hospital discharge*. The second option is an *invasive* treatment, in which case
 42 the process proceeds with a catheterization within the *Invasive strategy* phase,
 43 followed by the *Revascularization modalities* and the *Hospital discharge*. The
 44 last option is to apply *case management*. If the pathway is successfully walked
 45 through, the patient will leave the hospital through the *end event Departure*.

Table 3: Overview of the involved departments per phase of the pathway

	EHH	CCU	Twist	HCK	Heart team	CTC secr.	Twist	POS	OR	IC	Lab	Radiology	ENT	Oral surgery	Internal medicine	Pulmonary medicine
Initial evaluation	X										X					
Diagnosis	X	X	X								X					
Invasive strategy	X	X	X													
Revascularization																
PCI/meds		X		X												
(possible) CABG		X	X		X	X	X	X	X	X	X	X	X	X	X	X
Hospital discharge																
CAG/PCI/meds		X	X								X					
CABG							X			X	X	X				

1.2. Sub-Model for Initial Evaluation Phase

The *Initial evaluation* starts with the arrival of the patient either *by themselves* or by an *ambulance*, see Figure 3. The nurse will start with a short *anamnesis* while *attach patient to monitor* and *make and interpret ECG* to judge the current condition and exclude STEMI. Next, the patient might receive *nitrates* to relieve the chest pain. In all cases a *blood test* is done at the laboratory to determine the levels and values of among others *Troponin*, *Creatine Kinase (CK)* and *Creatine Kinase myocardial band (CKmb)*. In the meanwhile, the cardiologist continues with the interpretation of the *ECG* and conducts an *anamnesis* and *physical examination*. Then (s)he judges the *patients' history* and decides if the optional tasks 'give nitrates' and 'do an echocardiogram' are needed to perform. Subsequently a *working diagnosis* is made based on the gathered information and test results so far. For NSTEMI and UA patients, the pathway continues with the *calculate GRACE-score* (Global Registry of Acute Coronary Events-score) within the Electronic Medical Record (EMR) and the admission of the patient (*admit patient*) including the *open DOT*¹ for the financial administration. Before continuing to the next phase, patients with severe pain will be *given morphine*.

1.3. Sub-Model for Diagnosis Validation and Risk Assessment Phase

The care process proceeds with the *Diagnosis validation and risk assessment*, in which the more complex routing all has to do with the phase's goal

¹ *DOT* is a code for a treatment and stands for 'Diagnosis Treatment Combination's towards transparency'.

Figure 3: Sub-Model for the Initial Evaluation Phase

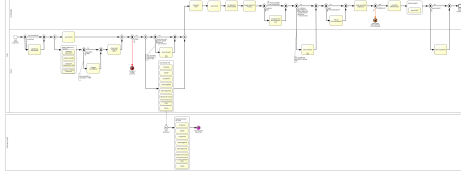
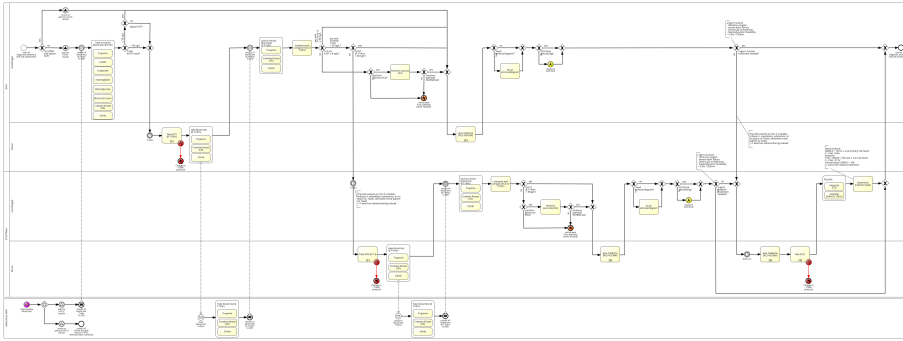


Figure 4: Sub-Model for the Diagnosis Validation and Risk Assessment Phase



68 to validate the diagnosis of UA and determine the according risk, see Figure 4.
 69 The diagnosis of UA is validated as the patient has typical ACS, a high sensitive
 70 troponin-T (hsTnT) level $\geq 30\text{ng/L}$ (that raised with $\geq 8\text{ng/L}$ in 3 hrs) and/or
 71 a positive exercise ECG. When UA is confirmed the patient is treated with the
 72 default medication, a possible *echocardiogram* is done and an indication is given
 73 for measuring the CK/CKmb levels in case they are not decreasing yet. After
 74 this, the cardiologist decides if an *urgent invasive treatment* is needed or not,
 75 see Table 4. In case of an urgent invasive treatment the patient's care continues
 76 within the *Invasive strategy* phase. In all other cases, the patient will be moved
 77 to the CCU or to the nursing ward of Cardiology (7west) and will receive the
 78 daily morning care (i.e., medication, ECG and rounds) there. During this round
 79 the further treatment of non-urgent invasive patients will be determined based
 80 on the GRACE-score and the presents of risks factors, see also Table 4 and
 81 Table 5. Patients assigned to an (early) invasive treatment continue within the
 82 *Invasive strategy* phase, the conservative treatment patients continue with the
 83 *Hospital discharge* phase.

84 1.4. Sub-Model for Invasive Strategy Phase

85 The *Invasive strategy* phase, see Figure 5, is initiated for patients assigned to
 86 an *invasive* treatment and in case of *emergency*. The phase always starts with
 87 the *sign patient up for CAG* (Coronary Angiography) by a cardiologist. This
 88 is followed for *emergency* and *urgent invasive* patients by the preparation and
 89 performance of the *CAG*. At night the HCK team on duty is paged in between

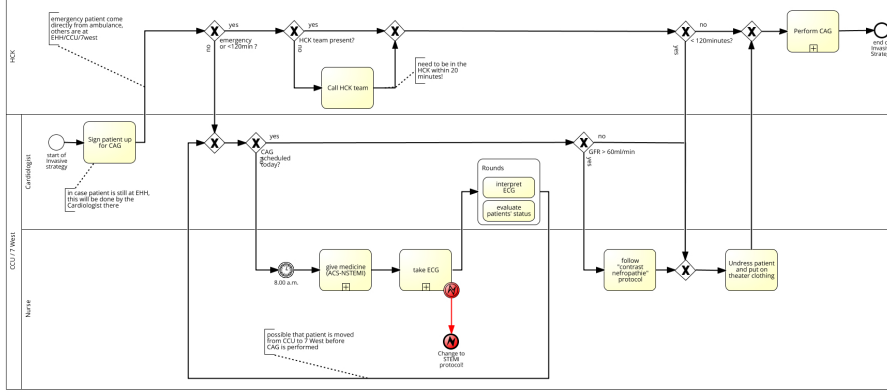
Table 4: Treatment plan options for ACS-NSTEMI/UA

Treatment	Indication	Plan
Urgent invasive	Refractory angina, severe heart failure, ventricular arrhythmias and/or hemodynamic instability	CAG < 120 min
Early invasive	GRACE score > 140 or ≥ 1 primary risk factor	CAG < 24 hrs
Invasive	$108 < \text{GRACE score} < 140$ or ≥ 1 secondary risk factor	CAG < 72 hrs
Conservative	GRACE score < 108, No additional risk factors	Treatment with medicines
Case management		Withdrawal from pathway

Table 5: Primary and secondary risk factors for the indication of the treatment of ACS-NSTEMI/UA

Primary risk factors	Secondary risk factors
Increased troponin	Diabetes Mellitus
Dynamic ECG changes	Renal insufficiency ($\text{GFR} < 60 \text{ ml/min/1.73m}^2$)
	Reduced Left Ventricular (LV) function ($\text{LVEF} < 40\%$)
	Early post infarction Angina
	Recent PCI or prior CABG
	Intermediate to high GRACE risk score

Figure 5: Sub-Model for the Invasive Strategy Phase



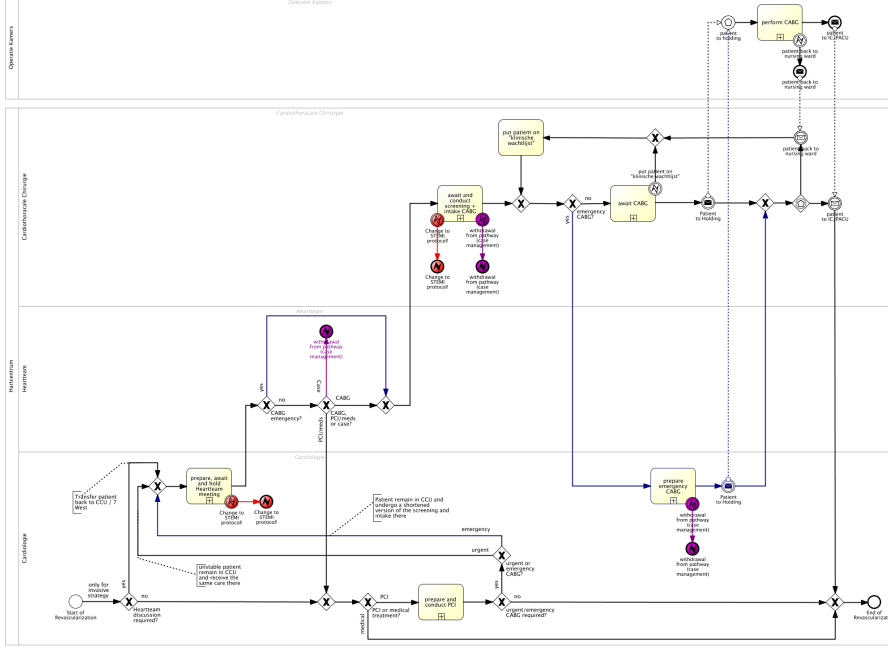
90 and will arrive at the hospital within 20 minutes. All other patients await their
 91 CAG at the ward (CCU and/or 7west) while receiving the daily morning care.
 92 Before they undergo the CAG, they will be prepared (e.g., clothing) and in case
 93 of a present renal failure (i.e., a $GFR < 60 \text{ ml/min}$) the kidneys will be purified
 94 according to hospital protocol. The treatment within the *Invasive strategy* phase
 95 ends after the CAG is performed.

97 1.5. Sub-Model for Revascularization Modalities Phase

98 The treatment in the *Revascularization modalities* phase (see Figure 6) starts
 99 with a choice between three treatment options, based on the information gath-
 100 ered by the CAG; (1) a *Percutaneous Coronary Intervention (PCI)* (i.e., sub-
 101 model *prepare and conduct PCI*), (2) a *medical treatment* (i.e., continue directly
 102 in the *Hospital discharge* phase)), or (3) consider a CABG (i.e., sub-model *pre-
 103 pare, await and hold heart-team meeting*). Most patients follow either (1) or
 104 (2). Besides that, it is possible that after the PCI (i.e., option 1) an *urgent or
 105 emergency CABG is required* (i.e., option 3). In all cases, the patient is trans-
 106 ferred from the HCK to the CCU or the CTC nursing ward (6west), where the
 107 preparation for the CABG will be done.

108 In case a CABG is considered, the *heart team meeting* will decide the further
 109 treatment plan for the patient. In case of a previous CAG this can be indeed the
 110 CABG (cf., sub-model *await and conduct screening + intake CABG*), but also
 111 a PCI (1) or medical treatment (2) after all, or case management. For patients
 112 that had a previous PCI, the only routings options are a CABG or *case man-
 113 agement*. The *await and conduct screening + intake CABG* sub-model starts
 114 with signing up the patient for the operation and furthermore contains several
 115 screening tests and consults to determine if the risk of undergoing a CABG
 116 surgery is acceptable. This risk is captured in the EuroSCORE (European Sys-
 117 tem for Cardiac Operative Risk Evaluation), a risk model that calculates the

Figure 6: Sub-Model for the Revascularization Modalities Phase

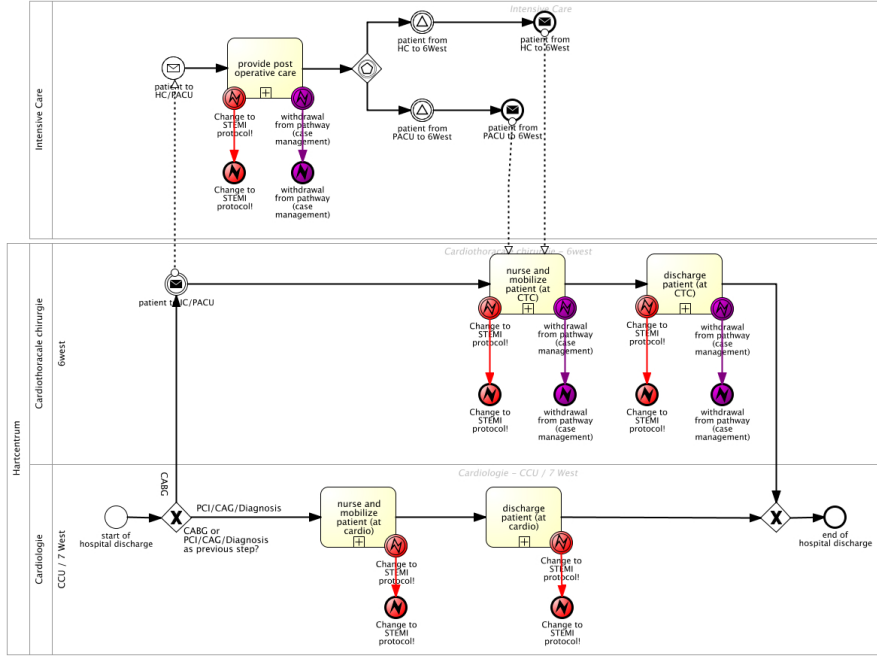


118 mortality probability after a heart operation, based on eighteen factors [1]. After
 119 the screening is concluded, the patient needs to await his/her surgery (i.e.,
 120 sub-model *await CABG*) or in case of an emergency CABG will be directly
 121 prepared for surgery (i.e., sub-model *prepare emergency CABG*). A distinction
 122 between sub-models is made because emergency patients remain on the CCU
 123 during the shortened sub phase of *await and conduct screening + intake CABG*,
 124 while all other patients will be transferred to 6west. The responsibility to per-
 125 form and coordinate the screening and intake of an *emergency CABG* operation
 126 remains with the CTC nurse practitioner and cardiothoracic surgeon, but the
 127 roles of nurse and secretary will be done by the CCU employees. During the
 128 sub phases of *await CABG*, *prepare emergency CABG* and the start of *perform*
 129 *CABG*, it is possible that the Anesthetist does not want to proceed and puts
 130 the patient back on the waiting list in case of an urgent or elective CABG or
 131 in case of an emergency CABG will withdraw the patient from the pathway.
 132 This phase ends when the sub phase *perform CABG* is walkthrough and the
 133 treatment continues within the *Hospital discharge* phase.

134 1.6. Sub-Model for Hospital Discharge Phase

135 The *Hospital discharge* phase contains out of two completely separated suc-
 136 cessful routings, which are initiated based on their prior step within the patients'
 137 assigned pathway, see Figure 7. All patients assigned to a *conservative treat-*
 138 *ment*, or an *invasive treatment with PCI or medical treatment* are treated at the

Figure 7: Sub-Model for the Hospital Discharge Phase



139 cardiology department according to the sub-models *nurse and mobilize patient*
 140 (*at cardio*) and *discharge patient (at cardio)*. During this phase the patients
 141 are monitored, mobilized and prepared for discharge while receiving the daily
 142 morning care. Before discharge they will be informed about the living rules for
 143 UA, receive medication prescriptions and make follow-up appointments.

144 All patients that have been assigned to an *invasive treatment with an elec-*
 145 *tive, urgent or emergency CABG* are treated at the ICU and 6west according
 146 to the sub-models *provide post operative care*, *nurse and mobilize patient (at*
 147 *CTC)* and *discharge patient (at CTC)*. Also these patients will be monitored
 148 and mobilized, but the processes heretofore are specific for the surgery they
 149 underwent. The discharge is quite similar as at cardiology, but there are some
 150 additional discharge tests, living rules to hold on to and follow-up appointments
 151 to make for these patients.

Appendix A. BPMN 2.0 elements and meaning

Table A.6: BPMN 2.0 elements and their meaning

Events			
	Start event		End event
	The process will be started when a message is received.		The process ends after a message has been send.
	The process is started with the escalation of it to another role in the organization.		This event activates the escalation of the process to another role within the organization, after which the process proceeds.
	The process waits until a message is received and progress afterwards.		A message will be send, after which the process proceeds.
	The process waits until a certain time has passed or until a certain moment in time before it continuous.		The process waits until a certain condition is met before proceeding.
	This symbol is always attached to the boundary of a <i>collapsed sub process</i> and 'catches' the error that has been 'thrown' within the sub process after which the process continuous with the flow connected to the error-symbol.		The process ends in an error-state, as a result from a 'thrown' error.
	The process waits until a certain signal is received before it proceeds.		A signal will be send, after which the process will proceed.
	Off-page catching event, whereby two corresponding events form a sequence flow.		Off-page throwing event, whereby two corresponding events form a sequence flow.
Activities		Gateways	
	A task is a unit of work.		An AND split or join, whereby all outgoing flows will be activated, or the process will wait until all incoming flows have arrived.
	Is a 'collapsed sub process' (an activity that can be split) of which the activities are visual in the diagram of the sub process.		A XOR split or join, whereby one of the outgoing flows will be activated based on their condition. Or whereby the process continuous after one of the incoming flows has been activated.
	Is a 'expanded sub process' wherein the sub process is directly visual.		An INCLUSIVE join, whereby the process waits until all activated incoming flows have been completed.
Associations			An EVENT-BASED split, whereby the process proceeds with the flow belonging to the first arriving message/signal.
	Sequence flow		
	Message flow		
	association		

References

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