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Analysis and Process Modeling of Triage Protocols - A Study in Emergency Departments in South Brazil

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“If I have seen further,
it is by standing on the shoulders of giants.”
— Sir Isaac Newton

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ABSTRACT

Emergency departments receive many patients suffering from a wide range of injuries or illnesses every day. The triage process is an essential mechanism to ensure these patients will be treated in their clinical urgency rather than arrival order. According to the literature, there are different triage protocols adopted worldwide, with four specific ones standing out as the triage process guide in several countries: The Australasian Triage Scale, the Canadian Triage and Acuity Scale, the Manchester Triage System, and the Emergency Severity Index. In this scenario, there has been a trend toward establishing standards and adopting a scientifically validated triage process to support clinical care, monitoring, and research activities in emergency departments, bringing direct benefits to patient care quality. To investigate the triage protocols context in the emergency departments in south Bazil, we performed a Process Discovery through a Business Process Management (BPM) approach. We extracted the process elements from the official triage protocols business documentation and generated its process models following a set of process modeling quality guidelines. Through a set of surveys with healthcare professionals with practical experience performing triage activities in Brazil's south emergency departments, we evaluate how BPM and the Business Process Model and Notation (BPMN) can improve the representation and standardization of triage protocols. Our findings indicate a good acceptance of the process models in BPMN in the opinions of the healthcare professionals interviewed, mainly by the adherence to the real triage process and its opportunity of practical use as triage guides or to illustrating to the incoming patients about the triage process performed in the emergency department. Additionally, we report a set of aspects about BPMN regarding the triage processes that emerged during the process model evaluation with the healthcare professionals.

Keywords: Triage Protocol. Healthcare Processes. Emergency Department. Business Process Management. BPMN.

Análise e Modelagem de Processos de Protocolos de Triagem - Um Estudo em Departamentos de Emergência no Sul do Brasil

RESUMO

Departamentos de emergência recebem diariamente uma ampla variedade de pacientes com vários tipos de problema, como ferimentos ou doenças. O processo de triagem é um mecanismo essencial para garantir que esses pacientes sejam tratados em sua urgência clínica, e não na ordem de chegada. De acordo com a literatura, existem diferentes protocolos de triagem adotados mundialmente, com quatro específicos se destacando como guia do processo de triagem em diversos países: o protocolo Australiano (*Australasian Triage Scale*), o protocolo Canadense (*Canadian Triage Acuity Scale*), o protocolo de Manchester (*Manchester Triage System*) e o protocolo Americano (*Emergency Severity Index*). Nesse cenário, tem havido uma tendência de se estabelecer padrões e adotar um processo de triagem validado cientificamente para apoiar o atendimento clínico, o monitoramento e as atividades de pesquisa em pronto-socorros, trazendo benefícios diretos à qualidade da assistência ao paciente. Para investigar o contexto dos protocolos de triagem no sul do Brasil, realizamos uma Descoberta de Processos por meio de uma abordagem com *Business Process Management* (BPM). Nós extraímos os elementos de processo da documentação de negócio oficial do protocolos de triagem e geramos seus modelos de processo, seguindo um conjunto de práticas de qualidade para modelagem de processos. Por meio de um conjunto de pesquisas com profissionais de saúde com experiência prática na realização de atividades de triagem em pronto-socorros do sul do Brasil, avaliamos como a BPM e a *Business Process Model and Notation* (BPMN) podem melhorar a representação e padronização dos protocolos de triagem. Nossos resultados indicam uma boa aceitação dos modelos de processo em BPMN na opinião dos profissionais de saúde entrevistados, principalmente pela adesão dos modelos ao processo de triagem real e pela oportunidade de uso prático desses modelos como guias de triagem, ou ainda, para ilustrar a pacientes sobre o processo de triagem realizado no pronto-socorro que eles buscaram. Adicionalmente, reportamos um conjunto de aspectos sobre BPMN representando processos de triagem que surgiram durante as validações dos modelos de process com profissionais da saúde.

Palavras-chave: Protocolo de Triagem. Processos da Saúde. Departamento de Emergência. Gerenciamento de Processos de Negócio. BPMN.

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LIST OF ABBREVIATIONS AND ACRONYMS

ATS	Australasian Triage Scale
AVPU	Acronym from "alert", "verbal","pain" and "unresponsive"
BPM	Business Process Management
BPMN	Business Process Model and Notation
CTAS	Canadian Triage Acuity Scale
DML	Decision Model and Notation
ED	Emergency Department
ESI	Emergency Severity Index
GCS	Glasgow Coma Scale
MTS	Manchester Triage System
OMG	Object Management Group
UML	Unified Modeling Language

CONTENTS

1 INTRODUCTION

Triage is an essential and structured mechanism used in the emergency departments worldwide to identify signs and symptoms, determine the patient's urgency level and to prioritize and transfer the patient to the appropriate place for treatment in an adequate time (MACKWAY-JONES; MARSDEN; WINDLE, 2014). In this context, identify the key symptoms quickly and make the correct clinical categorization can be life-saving.

According to the literature, there are different structured triage process, which is also known as triage protocol, adopted in emergency rooms worldwide. Between these protocols, four specific ones are standing out as the main triage process guide in many countries (CHRIST et al., 2010; BEVERIDGE et al., 1998; MCHUGH et al., 2012; VEEN et al., 2008):

- The *Australasian Triage Scale* (ATS): currently used in all publicly Australian and New Zealand emergency departments.
- The *Canadian Triage and Acuity Scale* (CTAS): adopted in all Canadian emergency departments.
- The *Manchester Triage System* (MTS): first created in Manchester city in England and then adopted in several European countries, like, Sweden, Spain, Holland, and in an adapted version, in German emergency departments.
- The *Emergency Severity Index* (ESI): adopted widely in the United States of America.

Although these protocols have the same goal, i.e., guide the triage process, they have meaningful and practical differences to the triage practitioner, influencing the triage dynamics in an emergency department (VEEN et al., 2008).

For example, the Australasian, Canadian, and Manchester protocols define time restrictions to start patient care. These three protocols also have in common the use of colors to highlight the patient's clinical classification. In contrast, the American protocol is the only one that evaluates expected resource needs (e.g., laboratory tests, intravenous medication) to determine the urgency level without defining an expected time interval to start the treatment (GILBOY et al., 2011).

Excepting the Australasian model, all other protocols have some definition or orientation about the patients' revaluation process (i.e., re-triage) (CHRIST et al., 2010).

1.1 Motivation

In an emergency department context, is vital the triage process accuracy and precision (MACKWAY-JONES; MARSDEN; WINDLE, 2014) on the patient clinical classification. For example, a clinical under-categorization can put a patients' condition at the risk of deterioration while waiting for treatment. In contrast, a clinical over-categorization can spend essential resources to the detriment of another patient who may require immediate care (GILBOY et al., 2011).

In this reality, there has been a trend toward establishing standards and the adoption of a scientifically validated triage process as a way to support clinical care, monitoring, and research activities in emergency departments, bringing direct benefits to patient care quality (American College of Emergency Physicians 2017, Gilboy et al. 2012). The literature also suggests a lack of standardization of triage assessments to the triage protocols, indicating challenges to nurses' adoption of triage protocols in emergency departments due to the deficiency of process orientation during the triage activity (HOHENHAUS, 2006; TRAVERS et al., 2009).

In Brazil reality, there was an effort to organize emergency services by the Ministry of Health in 2004 through an orientation on the health assistance provided in emergency departments (HEALTH, 2004). Although there is no explicit or formal regulation on how to implant a triage process (also known as Risk Classification) in an emergency department context, there is the recommendation to adopt a well-defined risk classification process and structured triage protocols (HEALTH, 2004; SOUZA; ARAÚJO; CHIANCA, 2015; Bellucci Júnior; MATSUDA, 2012).

Some attempts to adopt or adapt the triage process in an emergency department context showed the challenges of understanding the whole healthcare team about the structured emergency process. Mainly by keeping the focus on the patients' and nursers' needs and, at the same time, contemplate the administrative reality of each healthcare institution (COSTA et al., 2015; Bellucci Júnior; MATSUDA, 2012).

These triage protocols are a set of guidelines and policies that can also be seen as a healthcare process (COMBI et al., 2016) since it is partially planned, but at the same time driven by events, decision points, and availability of resources involved in the process. This environment's dynamism and complexity led to the adoption of process-oriented approaches and enterprise modeling to manage healthcare operations (SBAYOU et al., 2017). In this context, Business Process Management (BPM) is considered the leading standard

for discovering, analyzing, redesigning, executing, and monitoring business processes at different levels of abstraction and domains (DUMAS et al., 2018; MENDLING; REIJERS; AALST, 2009).

Though the advantages of adopting BPM in the healthcare domain, such as standardization of processes and improvement of their flexibility (De Ramón Fernández; Ruiz Fernández; Sabuco García, 2020), only a few works address the healthcare process modeling or representation with BPMN in current literature (ZERBATO et al., 2015). Some proposals suggest the application of BPMN combined with other structured approaches, such as the Unified Modeling Language (UML) (ZERBATO et al., 2015), or with the Decision Model and Notation (DMN) (COMBI et al., 2016). In contrast, other works focus on a more technical approach, as proposing a BPMN extension to specific medical processes contexts (BRAUN et al., 2014; MÜLLER; ROGGE-SOLTI, 2011). None of them address or discuss the triage protocols' particularities in an emergency department domain with a BPM approach.

1.2 Goals and Hypothesis

Our work aims to verify the conformity of the triage protocols described in the literature with what is practiced by healthcare professionals in emergency departments and discuss how a process-oriented approach and the Business Process Model and Notation (BPMN) can help in the representation and standardization of the triage process and triage protocols. The specific hypotheses (H) of this work are:

H1 *- Triage protocols are important to healthcare professionals performing the triage process in the Brazils' south emergency departments.*

H2 *- With a process-oriented approach, the BPM and its notation (BPMN 2.0) can improve the representation and standardization of triage protocols.*

From the established hypothesis, we defined the following specific goals (G):

G1 - Generate visual and description documentation of the triage protocol process.

G2 - Evaluate the adherence of the triage protocols process model to the triage process.

To achieve these goals, we followed existing techniques to discover processes from business documentation analysis and techniques for generating process models in this work.

1.3 Contributions

As the main contributions of this work, we highlight:

Quantitative survey results: We present the results of two quantitative surveys with healthcare professionals in different medical care centers (e.g., hospital, emergency care) located in the south of Brazil that we performed to achieve a better understanding of the adoption and the practical use of triage protocols in an emergency department context.

Triage Protocol Process Models: To evaluate and analyze the triage process described in the literature, we design and propose in BPMN notation the Triage Protocol Process Model and the Triage Protocol Process Description of the triage protocols utilized in this work.

Set of BPMN's recommendations: Based on our findings and the healthcare professionals' feedback, we report and discuss a set of BPMN's recommendations to represent triage protocols.

As a secondary contribution, we provide the questionnaire descriptions and the interview application process used on our survey to allow future researchers to reproduce our study in different contexts and build an empirical knowledge set.

1.4 Text Organization

This work subsequent chapters are organized as follows: Chapter 2 presents the triage protocols and BPM essential definitions to understanding this work. In this chapter, we also review existing research proposals addressing healthcare process modeling using BPMN.

Chapter 3 presents our preliminary study about the use of triage protocols in the emergency departments in south Brazil. Chapter 4 presents our triage protocols process discovery and process modeling to generate the triage protocols process models in BPMN notation. Chapter 5 shows our second survey performed to reach healthcare professionals with experience performing triage activities.

Chapter 6 presents the individual interviews performed with these healthcare professionals to evaluate our process models. This chapter also presents and discusses BPMN for triage process. Chapter 7 contains the finals conclusions, limitations, and future works of our research.

2 FUNDAMENTALS

The necessary background to understand this work is provided in this chapter. In the section 2.1 we introduce the main triage protocols in the literature. In the Section 2.2 the essentials definitions related to BPM and the businecess process lifecycle and process model quality.

2.1 Triage Process and Protocols

The English word "triage" comes from French, which means “sort" and its first use appeared in World War I to sort soldiers with different treatment priorities on the battlefields, essentially as an intuitive approach than a methodological or structured process (Canadian Association Of Emergency Physicians, 2013). Nowadays, triage is a clinical risk management method used in emergency departments worldwide to immediately identify signs and symptoms to define the patient’s urgency level, prioritize and transfer the patient to the appropriate treatments’ place in an adequate time (GILBOY et al., 2011).

This structured process of collecting subjective and objective information about the patients’ condition and the decision-making about the severity level is called triage protocol (MACKWAY-JONES; MARSDEN; WINDLE, 2014; Canadian Association Of Emergency Physicians, 2013).

According to the literature, there are different triage protocols used in emergency rooms worldwide, some with significant variations that could influence the triage dynamics (VEEN et al., 2008). There are triage protocols that use two-level urgency scales up to five-level urgency scales to classify patients, triage protocols that use colors to guide the urgency level classification and triage protocols that determine a time limit treatment.

Triage protocols with five-level urgency scales (i.e., Immediate, Very Urgent, Urgent, Standart and Non-Urgent) are the most recommended models for emergency departments because of the lower chance of a patient incurs in a clinical sublevel classification (CHRIST et al., 2010; GILBOY et al., 2011; WUERZ et al., 2000).

The main triage protocols used worldwide (VEEN et al., 2008; MACKWAY-JONES; MARSDEN; WINDLE, 2014) as the triage guide adopted in several countries are highlighted in the next subsections.

2.1.1 Australasian Triage Scale - ATS

This triage protocol was initially implemented in 1993 as the National Triage Scale (NTS) by the Australasian College for Emergency Medicine. In 2000 the NTS protocol was revised and renamed to *Australasian Triage Scale* (ATS) and is currently in use in Australia and New Zealand. The ATS model focuses on responding adequately and in a short time (depending on severity) to patients seeking emergency services (HEALTH; AGEING, 2009c; HEALTH; AGEING, 2009b).

The triage assessment is conducted by staff members who are both specifically trained and experienced in healthcare, usually a triage nurse. Although the triage process proposes an urgency level classification, the triage assessment is not intended to make a clinical diagnosis (MEDICINE, 2016; HEALTH; AGEING, 2009a).

According to the patients' severity, the ATS protocol uses a five-level urgency scale (i.e., categories) to apply a clinical classification. The use of colors (i.e., red, orange, green, blue, and white) is adopted to visually identify each triage category and indicate the maximum time the patient can wait for assessment and treatment. For example, in the highest category, assessment and treatment should occur simultaneously.

This triage protocol also stands out by a set of performance indicators on the time-to-treatment metrics that are routinely evaluated on nationally recommended performance standards for each of the five ATS categories. Although it is relatively intuitive and straightforward, the ATS protocol is also applicable to more complex cases such as pediatrics, traumatology, and patients with mental and behavioral disorders (VEEN et al., 2008; CONSIDINE; LEVASSEUR; VILLANUEVA, 2004). Table 2.1 resumes the ATS main triage information.

Table 2.1: Australasian Triage Scale - Classification

Classification	**Description**	**Max Time**	**Indicative Color**
Category 1	Immediately life-threatening	Immediate	Red
Category 2	Imminently life-threatening	10 minutes	Orange
Category 3	Potentially life-threatening	30 minutes	Green
Category 4	Potentially life-serious	60 minutes	Blue
Category 5	Less urgent	120 minutes	White

Soure: Adapted from Health and Ageing (2009c)

2.1.2 Canadian Triage Acuity Scale - CTAS

The Canadian model was developed by the Canadian Association of Emergency Physicians (CAEP) using the Australasian Triage Scale as an initial model. It has been widely adopted in Canada's emergency services since its first publication in 1999 (BEVERIDGE et al., 1998). The Canadian protocol is continually reviewed by the CAEP group considering variables such as the workload in emergencies and the adaptation of the model to attend adult patients and pediatrics. Like the ATS protocol, the CTAS model also indicates an experienced nurse with formal training to perform the triage assessment.

Although the similarities with the Australasian triage protocol, this model is more explicit by indicating specific clinical conditions (i.e., signs and symptoms) as triage process inputs and also by specifying time reevaluation (re-triage) according to the patient's level of care. Another interesting difference is that this model does not use colors to indicate the levels of the classification (BEVERIDGE et al., 1998; MURRAY; BULLARD; GRAFSTEIN, 2004). Table 2.2 resumes the CTAS main triage information.

Table 2.2: Canadian Triage Acuity Scale - Classification

Classification	**Description**	**Time**	**Conditions examples**
Level 1	Resuscitation	Immediate	Cardiac arrest; unconscious
Level 2	Emergent	$\leq$ 15 min	Head injury; severe trauma
Level 3	Urgent	$\leq$ 30 min	Asthma; moderate dyspnea
Level 4	Less Urgen	$\leq$ 1 hour	Headache; minor trauma
Level 5	Non Urgent	$\leq$ 2 hours	Sore throat; abdominal pain

Soure: Adapted from Beveridge et al. (1998)

2.1.3 Manchester Triage System - MTS

The Manchester model was developed through the research of the Manchester Triage Group (MTG), based on the nurse's and doctor's requirements about achieving consent based on evidence on the prioritization of patients' care in the emergency services (MACKWAY-JONES; MARSDEN; WINDLE, 2014; SOUZA; ARAÚJO; CHIANCA, 2015; PARENTI et al., 2014). Its first use was in 1997 in Manchester city in England, and today it is adopted in several countries of Europe, like Sweden, Spain, and Holland.

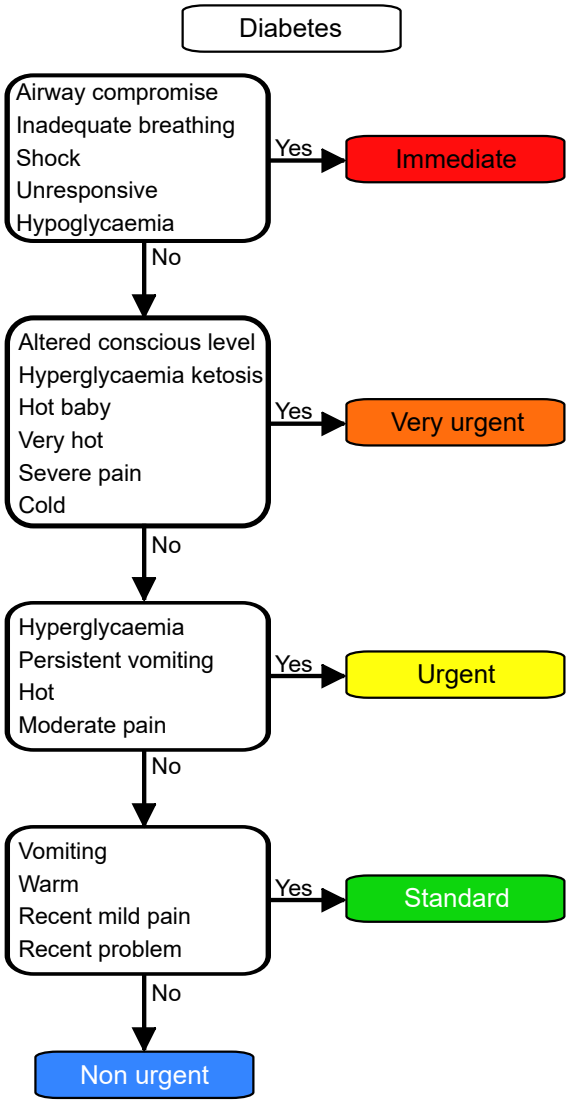
Like other protocols, the Manchester model also uses a color scale (GROUSE; BISHOP; BANNON, 2009; AZEREDO et al., 2015; PROVIDÊNCIA et al., 2011) to indicate the clinical classification and determines a maximum waiting time according to patient care's urgency. The triage nurse uses the patient or family member's complaint as input to select one of 55 algorithms (also known as flowcharts). These diagrams have a list of key symptoms in an urgency scale, considering the potential threat to life, pain scale, or the patient's consciousness level, and it is used to guide the triage process. Table 2.3 lists all the 55 flowcharts present in the MTS protocol and Fig. 2.1 illustrates the emergency levels in a *diabetes* situation (MACKWAY-JONES; MARSDEN; WINDLE, 2014).

Table 2.3: List off all 55 flowcharts present in the MTS protocol

Flowcharts		
Abdominal pain in adults	Ear problems	Rashes
Abdominal pain in children	Eye problems	Self-harm
Abscesses/infections	Facial problems	Sexually acquired infection
Abused or neglected child	Falls	Shortness of breath in adults
Allergy	Fits	Shortness of breath in child
Apparently drunk	Foreign body	Sore throat
Asthma	Gastrointestinal	Testicular pain
Assault	Headache	Torso injury
Back pain	Head injury	Unwell adult
Behaving strangely	Irritable child	Unwell baby
Bites and stings	Limb problems	Unwell child
Burns and scalds	Limping child	Unwell newborn
Chemical exposure	Major trauma	Urinary problems
Chest pain	Mental illness	Worried parent
Collapsed adul	Neck pain	Wounds
Crying baby	Overdose/poisoning	Major incident – primary
Dental problem	Palpitations	Major incident – secondary
Diabete	Pregnancy	
Diarrhoea and vomiting	PV bleeding	

Soure: Adapted from Mackway-Jones, Marsden and Windle (2014)

Figure 2.1: The MTS flowchart used to assess the patient with *diabetes* suspect.



Source: Adapted from Mackway-Jones, Marsden and Windle (2014)

2.1.4 Emergency Severity Index - ESI

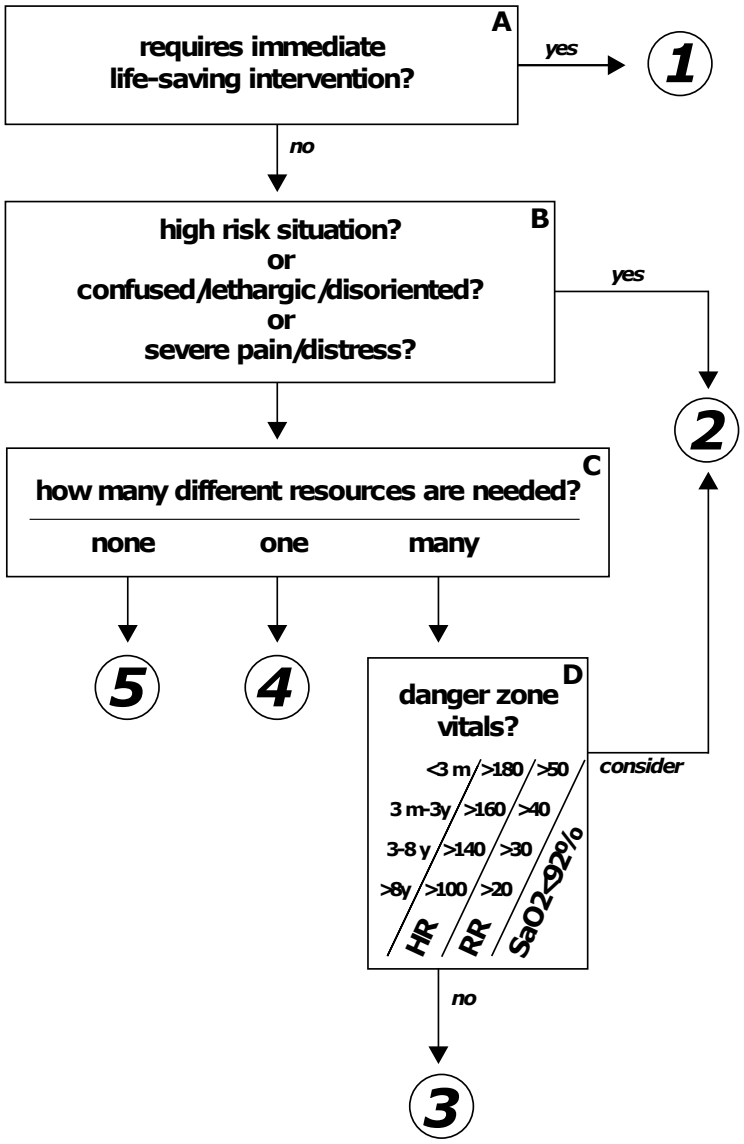
This triage protocol is also known as the American model. Its first version was developed in 1999, initially addressing only adult patients. In 2000, based on feedback from nurses and physicians and the available scientific evidences, the model was improved considering assessments of vital signs on a pediatric scale. This model has been widely used in emergencies in the United States of America (STORM-VERSLOOT et al., 2011; TRAVERS et al., 2009; STORM-VERSLOOT et al., 2009).

The American model considers a specific algorithm with five severity levels, where level one is the most urgent, and level five is the least urgent. Each part of the triage algorithm has explanatory notes with technical information, which helps the nurses evaluate and assess the patients (Van Der Wulp; SCHRIJVERS; Van Stel, 2009).

Unlike other models, this model considers in its flow the number of required resources for patient care. For example, if a blood test and a urine test are needed to determine the patient's condition, they will count as a single resource (i.e., laboratory tests). If a chest X-ray is also needed, it will count as another resource (GILBOY et al., 2011), as shown in Fig. 2.2.

The evaluation of resource needs in the triage process is a singular feature of the ESI in comparison with other triage triage protocols.

Figure 2.2: The ESI triage algorithm.



Source: Reproduced from Gilboy et al. (2011)

2.1.5 Protocols Differences and Similarities

It is possible to observe significant differences between the triage protocols listed above. Unlike the other protocols, the American model does not define a time limit for patients to be evaluated by a specialist but indicates clinical conditions and resources needed along the triage process. It can also be considered the only model that contemplates the anticipation or prospection of exams for the triage process.

Regarding pediatric care, the Manchester model has specific flowcharts for children. Simultaneously, the American protocol considers only a few children's scales to analyze vital signs to determine the emergency category. The Canadian model has a specific version of its guide for pediatric use.

Except for the American model, all other protocols use a list of key diagnoses or symptoms to define the urgency of patients' level. However, this model may lead to a subclassification of the urgency level assigned to the triage process (CHRIST et al., 2010; BULLARD et al., 2017; GRÄFF et al., 2014).

It is possible to note that all models described use scales of five levels (e.g., red, orange, yellow, green, and blue). Triage protocols that use classification at five-priority levels are superior to validity and reliability than models that use only three-rating levels (CHRIST et al., 2010; RUTSCHMANN et al., 2018).

A comparative between the triage protocols' features and their differences is presented in Table 2.4.

Table 2.4: Triage protocols comparative.

Features	***ATS***	***CTAS***	***ESI***	***MTS***
Five-level scale	Yes	Yes	Yes	Yes
Specifc algorithm	No	No	Yes	Yes
Use of colors	Yes	Yes	No	Yes
Use in the country	Yes	Yes	No	Yes
Key discriminants	Yes	No	Yes	Yes
List of symptoms	No	No	No	Yes
Re-triage process	Not specified	Specified	As required	As required
Pediatric cases	Not specified	Special version	Considered	Considered

Soure: Adapted from Christ et al. (2010)

2.2 Business Process Management

A business process is a set of collaborative and dynamically related activities, events, persons, and decision points, with the main goal of delivering value to a consumer through a product or a service (WESKE, 2012). In this scenario, the BPM discipline is a collection of methods and tools to address the activities of identify, analyze, model, and managing business processes (DUMAS et al., 2018). BPM can also be seen from a lifecycle perspective determined by a set of phases and activities that have defined objectives and are directly correlated.

Several authors have proposed different BPM lifecycles in books and papers, such as Aalst (2013), Brocke and Rosemann (2015), Hallerbach, Bauer and Reichert (2008), Muehlen and Ho (2006), and Weske (2012). To describe BPM phases, in this work, we present the lifecycle proposed by Dumas et al. (2018) because it is complete and easy to understand, reaching different BPM levels of abstractions in its execution.

The BPM lifecycle proposed by Dumas et al. (2018) is presented in Fig. 2.3. This lifecycle consists of 6 specifics phases, described as follows.

Process identification: This first phase aims to identify and define a specific business problem. All the processes relevant to these business problems are identified, delimited, and interrelated in this phase. The process identification outcome is a process architecture that provides an overview of the processes and their relationships. This architecture is used as input to the remaining phases of the lifecycle.

Process discovery: Each relevant process identified is understood and modeled in the current state. There are different methods for gathering information about an existing process: an *evidence-based* method through document analysis, observation, and automated process discovery; an *interview-based* method with domain experts to inquire about how the process is executed; and a *workshop-based* method with a group of domain experts. The result of this step is a set of *as-is process models*.

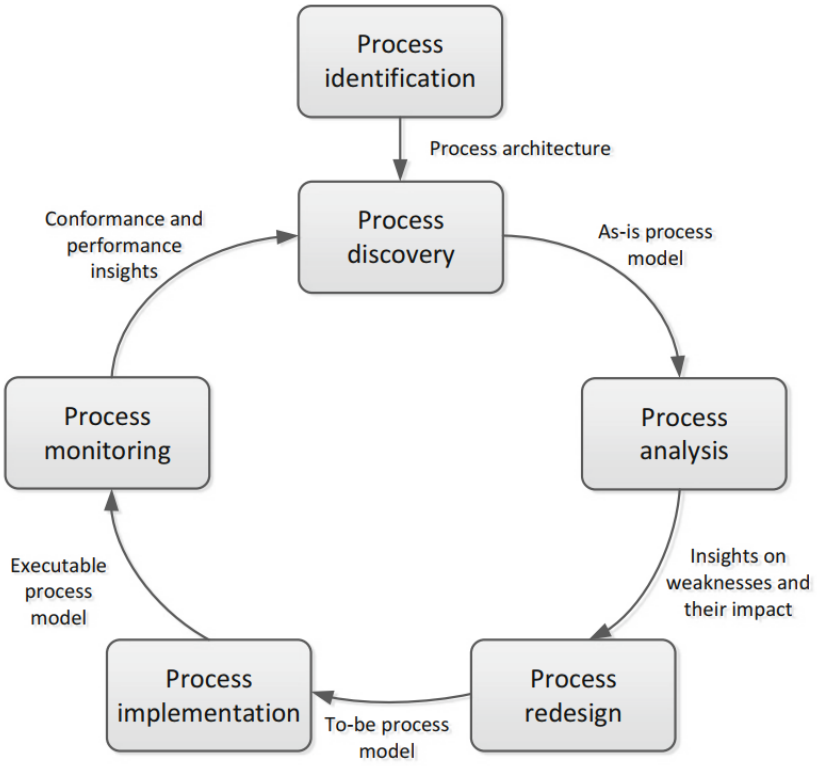
Process analysis: In this phase, qualitative and quantitative analyses are conducted about the as-is process, identifying and documenting the process improvement opportunities. This phase's output is a set of prioritized insights on the business process's weaknesses and impacts.

Process redesign: This phase aims to identify changes to the process that address the issues based on the process analysis observations. This phase is also called process improvement, and this phase's output is a set of *to-be process models*.

Process implementation: This phase aims to prepare and perform the necessary changes to implement the as-is process model into the to-be process model, focusing on the organizational changes (i.e., the company way of working) and the process automation through the development of IT systems.

Process monitoring: In this phase, the redesigned process is monitored to collect and analyze the output data and determine whether the process performs according to its performance indicator. New outcomes may appear in the process, or even new processes arise, requiring a new cycle iteration.

Figure 2.3: BPM lifecycle



Source: Reproduced from Dumas et al. (2018)

Since this work aims to elaborate the triage protocol process models through the document analysis and evaluate the models with domain experts (i.e., healthcare professionals) through individual interviews, we highlight that this work is strongly correlated to the process discovery phase.

2.2.1 Business Process Model and Notation

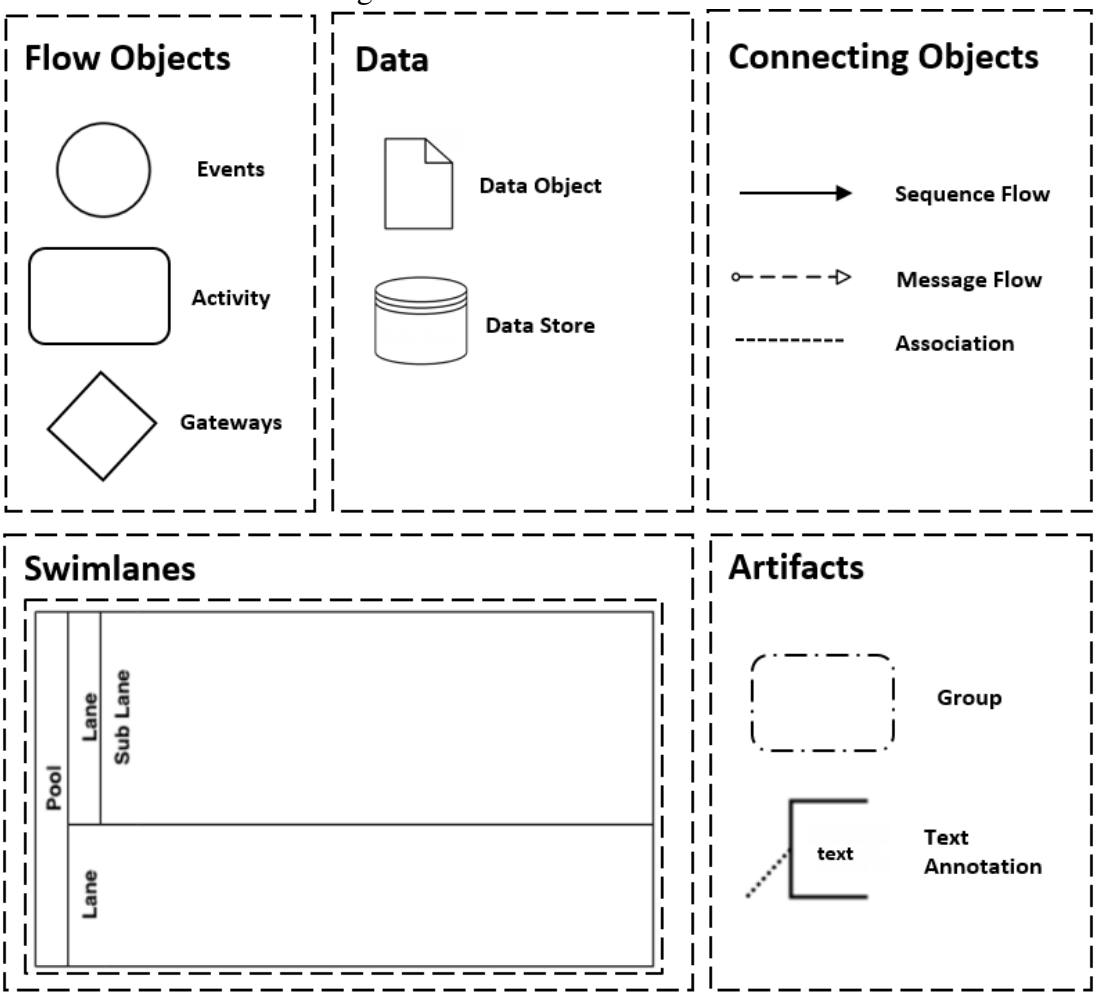
Maintained by the Object Management Group (OMG) since 2006, the BPMN developed as a standard language for business process representation that all business users can understand at different levels of abstraction and application domains. The BPMN is currently available at version 2.0 and is recognized as an official ISO standard (ZERBATO et al., 2015; OMG, 2013).

A BPMN process is defined as a sequence of events and activities connected by a sequence flow representing all the paths that can be taken to reach a particular (business) objective (WESKE, 2007). To represent a process, BPMN 2.0 provides a variety of elements with different functions (OMG, 2013), organized in five basic categories of elements: *Flow Objects* (events, activities, and gateways) are the main graphical elements because they define the behavior of a business process; *Data* (data objects, data inputs, data outputs, and data stores); *Connecting Objects* (sequence flows, message flows, associations, and data associations) are used to connects Flow Objects; *Swimlanes* (pools and lanes) and *Artifacts* (groups and text annotations) that are used to provide additional information about the process. Fig. 2.4 shows the BPMN 2.0 basic elements. The main BPMN modeling elements are explained as follows.

Events: represent something that happens instantaneously along the business process (e.g., "patient arrived in the Emergency Department", "laboratory exams requested"). These Event affects the flow of the model and has a cause or an impact. Events are graphically represented as circles with open centers to allow internal markers to differentiate different causes or impacts. It can be of three types based on the moment the event affects the process flow: a *Start*, an *Intermediate*, or an *End* event. An Event can also receive a particular marker to represent specifics conditions. For example, a *Timer Event* (an event with a clock tag in the center of the circle) represents points in time, periods, or process timeouts. An *Escalation Event* (an event with an arrow in the center of the circle pointing up) represents a process escalating to a higher level of responsibility.

Activities: represents the work performed during the process (e.g., "evaluate the patient", "fill the nurses' report") and is represented as rounded boxes. When an activity can be seen as a single unit of work, it is called *task*; otherwise, it is called *activity*. When a process model is too complex (e.g., it contains more than 50 elements), (MENDLING; REIJERS; AALST, 2009), its elements can be grouped in a sub-process. A sub-process represents a subset of activities that may be grouped to improve the process readability.

Figure 2.4: BPMN basic elements



Source: The authors, adapted from OMG (2013)

Gateways: these elements are used to express the decision points along the business process and are represented as a diamond shape. They are responsible for controlling divergence (split) and convergence (join) of sequence flows in a process. Thus, a gateway can lead to different paths (split) or join different paths within one (join). A *path* can be defined as a set of flow objects connected sequentially through sequence flows along the process. Gateways have three main types. An *Exclusive Gateway* (XOR), represented with an "X" marker in the center of the diamond, is when the decision making leads to the execution of only one path (e.g., "the patient must be either allocated at the urgent area or the non-urgent area"). A *Parallel Gateway* (AND), represented with a "+" marker in the center of the diamond, is when all possible fallow paths must be executed (e.g., "the nurse must assess the patient blood pressure" also with "the nurse must assess the patient breathing condition"). An *Inclusive Gateway* (OR), represented with an "circle" marker in the center of the diamond, is when the decision making leads to the execution of at least

one path (e.g., "the physician must evaluate the patient medical records" or "the physician must request a new laboratory exam").

Data objects: represent a singular object or a collection of objects required or produced by activities along the process. A *Data Object* (represented by a paper sheet) represents information flowing through the process, such as medical records, documents, e-mails, or forms. A *Data Store* (represented by a database) is where the process can read or write data, and it persists beyond the lifetime of the process instance.

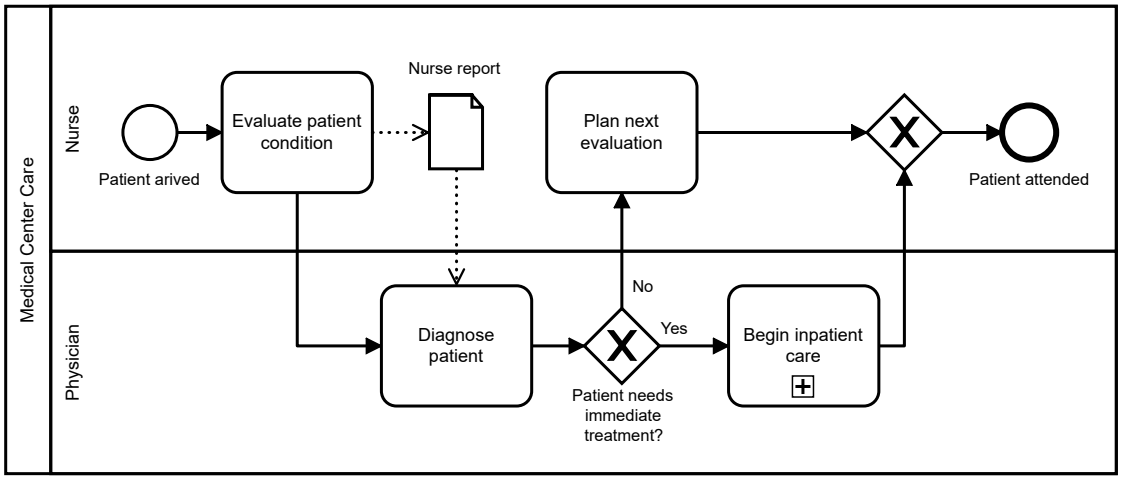
Connecting Objects: these elements are used to connect the flow objects to each other or other element types, representing the order through which a process will be executed. The main types of connecting objects are: *Sequence Flows* connect two different flow objects and represent the order in which the process is executed. It is represented as a single solid line with a solid arrowhead; *Message Flows* connect flow objects of two different pools, representing the communication of messages between two participants along the process. It is represented as a single dashed line with an open circle line start and an open arrowhead line at the end; an *Association* is used to link information and artifacts with flow objects.

Pools represent the process' participants, grouping the activities realized by these participants. A pool may be divided by swimlanes (or lanes) representing the different actors present inside this pool. It is graphically represented as a container that partitions a process from other participants. *Lanes* are used to divide a pool into different organizations' resources, representing internal roles and their activities (e.g., nurse, physician), applications (e.g., the healthcare IT system), or an internal department (e.g., emergency department, resuscitation room).

Artifacts are used to provide additional information about the process. There are two standardized artifacts: *Group* (a box around a group of objects) is a grouping of elements that the same category. This type of grouping does not affect the Sequence Flows; *Text Annotation* (attached to an element with an Association) provides additional text information about a specific process flow or the business process model. A basic example of a healthcare process modeled in BPMN notation is showed in Fig. 2.5.

Process Description: This triage process is executed by a *Nurse* and a *Physician*. This process starts when a patient arrives (Event: *Patient arrived*) in the Medical Center Care (Pool: *Medical Center Care*). The nurses' first step is to evaluate the patients' clinical condition (Activity: *Evaluate patient condition*), generating the Nurse Report as output (Data Object: *Nurse Report*).

Figure 2.5: BPMN basic elements in a healthcare process example



Source: Adapted from Dumas et al. (2018)

The physician uses this report to diagnose the patient (Activity: *Diagnose patient*) and decide whether the patient needs immediate treatment or not. In case the patients' condition requires instant attention, it is necessary to begin the inpatient care proceedings (Sub-process: *Begin inpatient care*). Otherwise, the process goes back to the nurse plan for the next patient evaluation (Activity: *Plan next evaluation*). The process finishes with the patient attended in the Medical Center Care (Event: *Patient Attended*).

2.2.2 Process Model Quality

An important aspect of collecting and organizing process-related information in a process model is ensuring that the model produced is of high quality. We can observe three quality aspects of a process model: syntactic, semantic, and pragmatic quality (DUMAS et al., 2018; MENDLING; NEUMANN; AALST, 2007; OCA; SNOECK; CASAS-CARDOSO, 2014).

Syntactic quality is related to the process model's compliance with the modeling language's syntactic rules. For example, activities must have at least one incoming sequence flow. Ensure this quality aspect is important to increase the model understandability and to avoid ambiguity.

There are two types of syntactic rules: structural and behavioral rules. Structural rules are related to the way the process elements are connected between themselves in a process model. A set of structural rules by the element level are listed in Table 2.5.

In contrast, behavioral rules are required to avoid behavioral anomalies such as *deadlocks* (when a process instance cannot progress due to other activities) and *livelocks* (when a process instance runs in a loop forever) during a process model's execution. This kind of irregularity can appear, for example, when mixing a split with a join of a different gateway type in the same group of elements in a process model (DUMAS et al., 2018).

Table 2.5: Structural rules acording to BPMN elements

Element	**Structural rules**
Activities	-Activities must have at least one incoming and one outgoing sequence flow;
Events	-Start events must not have incoming sequence flows; -End events must not have outgoing sequence flows; -Intermediate events must have at least one incoming and one outgoing sequence flow; -Only intermediate catching boundary events can be attached to an activity's border;
Gateways	-Split gateways must have exactly one incoming and at least two outgoing sequence flows; -Join gateways must have at least two incoming and exactly one outgoing sequence flows; -The outgoing arcs of an XOR-split gateway must bear conditions;
Flows	-A sequence flow must connect two flow nodes (activities, events, and gateways) of the same pool, i.e., sequence flows cannot cross the boundaries of pools; -A message flow must connect (an activity or a throwing message event in) one pool with (an activity or a catching message event in) a different pool; -A directed data association must connect a data object with an activity or message event; -An indirected data association must connect a data object with a sequence flow, or a text annotation with any element;

Soure: Adapted from Dumas et al. (2018)

Semantic quality is the adherence of a process model to its real-world process. Although there are no formal rules set to check this aspect, this can be achieved by consulting the process participants, the domain experts or the available documentation.

Pragmatic quality is related to the usability of a process model and focuses on how well a user understands it. A significant mechanism for improving the pragmatic quality is the modeling guidelines, and, in this aspect, the work "*Seven Process Modeling Guidelines (7PMG)*" by Mendling, Reijers and Aalst (2009) is a prominent example.

These guidelines were developed based on a robust empirical foundation while also trying to keep the instructions simple and helpful to guide users towards the process modeling activity (AVILA et al., 2019; OCA; SNOECK; CASAS-CARDOSO, 2014; BECKER; ROSEMANN; UTHMANN, 2000). The 7 PMGs are listed in Table 2.6.

Between the specific objectives for using modeling guidelines, we highlight the positive impact of the model consistency, the increase of standardization and reuse, and the facilitation of the models' access by non-modeling experts (DUMAS et al., 2018).

Table 2.6: The Seven Process Modeling Guidelines (7PMG)

	Guidelines
G1	Use as few elements in the model as possible
G2	Minimize the routing paths per element
G3	Use one start and one end event
G4	Model as structured as possible
G5	Avoid OR routing elements
G6	Use verb-object activity labels
G7	Decompose a model with more than 50 elements

Soure: Adapted from Mendling, Reijers and Aalst (2009)

Another important aspect that can affect the pragmatic quality during a business document analysis is the generation of a process model with ambiguous or nonrecurring sentences (SILVA et al., 2018; DIKICI; TURETKEN; DEMIRORS, 2018; AA; LEOPOLD; REIJERS, 2018), which could make it challenging to understand the process.

A sentence is considered ambiguous when it allows multiple interpretations of the process. For example, The expression "and" to describe a set of activities can lead to different meanings, implying a relationship of sequence, dependence, or even parallelism (SILVA et al., 2018). Table 2.7 shows a list of examples of ambiguity.

Table 2.7: Examples of Ambiguity

Description	**Example**
The term “and” can have different meanings, such as: sequence, dependence, parallelism, contrast	*The employee must update the document and prepare the product for shipping*
The terms “or” and “sometimes” may raise doubts whether it includes or is mutually exclusive to the different alternatives.	*(1) The document is accepted or denied. (2) The bicycle can be mounted orpainted*
The term “latter” usually does not make clear to what previous activities it refers	*In parallel to the **latter** steps...*
The terms “meanwhile”, “concurrently”, “meantime”, “in the meantime” and “at the same time” make it difficult to specify which sets of activities they refer to	***In the meantime**, the sales department must prepare the receipt*
Repetitions usually not clear what activities should be performed again	*The previous steps must be **repeated***
The term “while” can mean simultaneity or concession	***While** it is true that the company has the money, they can’t build the houses*

Soure: Reproduced from Silva et al. (2018)

2.3 Related Work

In current literature, a few proposals address healthcare process modeling using BPMN (ZERBATO et al., 2015) in different levels of perspectives. Some approaches suggest the use of BPMN together with other structured approaches in specific contexts.

A project proposed by Scheuerlein et al. (2012) uses BPMN and Tangible Business Process Modeling (t.BPM) to model two clinical pathways to treat colon and rectum carcinoma. Both healthcare processes were modeled over 15 working days. As a result, they state that the application of BPMN in medicine is new and possible, used for teaching and training, patient information, and quality management. The integration of a modeling language, such as BPMN, into the hospital computer systems could be a very sensible approach for developing new hospital information systems in the future.

The work proposed by Kopecky and Tomaskova (2020) demonstrates the use of

BPMN to illustrate the complex process of treatment and care of Alzheimer's patients. This BPMN model was planned to specify the transition conditions between different disease stages and diagnose and treat the individual symptoms. Furthermore, this model would be possible to simulate different disease patterns at different time intervals according to the disease evolution.

Zerbato et al. (2015) proposed a methodology based on BPMN and UML for modeling healthcare processes, indicating the high dependency of the process from the data necessary to its correct flowing. This work modeled two clinical pathways for catheter-related bloodstream infections adopted in two hospitals in Europe and the U.S, reaching care quality improvements in terms of process and data management to the hospital context. BPMN is also related to the use of DMN (Decision Model and Notation) (COMBI et al., 2016) to deal with healthcare processes and related decision-making design. This approach was applied to the management of patients affected by Chronic Obstructive Pulmonary Disease.

Some works focus on a more technical approach, such as addressing healthcare process modeling by proposing a BPMN extension. Named "BPMN4CP" (BRAUN et al., 2014), this BPMN extension introduces three new types of the *Task* element: *Diagnosis Task*, *Support Task* and *Therapy Task* to subdivide the treatment into different and distinct steps. The *Data Object* element was also adapted to represent the document used in the healthcare process (e.g., Patient File). In the second version of this work (BRAUN et al., 2016), this BPMN extension was revised, intending to reduce complexity by adding separate diagrams for representing resources and documents involved in the process.

To address problems about roles and task assignments in healthcare processes, another BPMN extension is proposed (MÜLLER; ROGGE-SOLTI, 2011) with the use of color attribute of tasks as a complementary visualization to the lane element. In this approach, colored tasks are used instead of different lanes to capture role information more compactly but without addressing problems with tasks performed by different roles.

2.4 Final Considerations

As shown, there are approaches addressing healthcare process modeling by the use of BPMN in the literature. Some of these works adopt BPMN combined with other structured approaches (SCHEUERLEIN et al., 2012; KOPECKY; TOMASKOVA, 2020; ZERBATO et al., 2015; COMBI et al., 2016), usually in specific medical processes or

specifics disease treatment mapping. Some BPMN extensions (BRAUN et al., 2014; BRAUN et al., 2016; MÜLLER; ROGGE-SOLTI, 2011) are also a solution explored in the literature to address process modeling limitations in specifics domains. None of them address or discuss the triage protocols' particularities in an emergency department domain with a BPM approach.

Our work focused on exploring the triage process through a process-oriented approach with BPM, starting with a process discovery from the official triage protocols implantation guidelines. Then, through a set of surveys, evaluating the process models adherence with healthcare professionals who have experience background performing the triage process. Based on the findings and the healthcare professionals' feedback, this work also reports and discusses a set of BPMN's recommendations to represent triage protocols from an emergency department perspective.

3 PRELIMINARY STUDY

This chapter presents the preliminary study we conducted to better understand the use of triage protocols for healthcare professionals in Brazils' south emergency departments.

This first quantitative survey was strongly related to the hypotheses and goals of this work. First, verifying whether triage protocols are used (and which ones) by the healthcare professionals to perform triage activities would guide us to generate the visual and description documentation of the triage protocols (our goal G1). Second, achieving consistent information about how important these triage protocols are to healthcare professionals would allow us to verify our first hypotheses (H1) and identify existing opportunities to be further explored in the triage process field.

3.1 Survey Application

This first survey was an online questionnaire composed of 12 questions: 11 objective questions and one discursive question, separated into three specific sessions.

The first questionnaire session was an introductory message about the academics researchers and the survey goal (i.e., collect information about the adoption of triage protocols in emergency departments). We also highlighted that no personal information would be collected during the survey.

In this questionnaire first session, we also collected demographic information about the survey respondents: (i) academics degree (e.g., medicine graduate, nursing graduate); (ii) experience time performing triage process; (iii) main healthcare unity type where the respondent has worked (e.g., Hospital, Emergency Care Unit); (iv) the city of this healthcare unity. No other personal information about the respondent or the healthcare unit was requested or collected in this survey questionnaire.

The second session was about the triage protocols identification by the respondents. They were asked to inform if they use any triage protocol to perform triage activities. We also asked the respondent to inform the specific triage protocol they know or use in their triage activities.

The last session of the questionnaire was about collecting information on the triage protocols practical use. If the respondent used a protocol different from the four triage protocols listed, we requested them to select the characteristics this specific protocol had,

as maximum time definition, five-level classification, or use of colors. Finally, we asked the respondent to inform how important it is to have a protocol for the triage process in the respondent's opinion.

The last question was an open question where the respondent could inform how the triage protocol most helped to perform triage. The complete questionnaire applied with all the questions is attached to this work in Appendix A.

This first study was available online from 20 March to 24 May 2019 and involved 36 participants that answered our questionnaire. We used convenience sampling to invite the participants, where we sent the online survey link by e-mail to the researcher's contacts network. We also published a call for participation in different social media (e.g., Facebook, Twitter).

3.2 Survey Analysis

Since the researchers involved in this study are from Porto Alegre/Brazil and its metropolitan area, most participants are from this region (94%). The remainder sample (6%) is from two other states of Brazil: São Paulo and Espírito Santo.

Considering that our research focuses on Brazil's south region, we discarded these surveys from other Brazil states. The analysis in this session will be over all the 34 participants from Brazil's south region.

3.2.1 Demographic Information

About the respondent's academics degree, our sampling was predominantly *Nursing graduate* (38%) and *Nurse technician licensed* (29%), while *Doctors* were only 15%. Since our survey was directed to healthcare professionals with experience performing triage activities, this finding implies that the triage process is performed mainly by nurses, as highlighted in some triage protocol adoption guidelines (MACKWAY-JONES; MARSDEN; WINDLE, 2014; GILBOY et al., 2011).

Table 3.1 shows the respondents' academics degrees distribution on this survey.

Table 3.1: Education degree of the respondents.

Education degree	***N***	***%***
Nursing graduate	13	38
Nursing student	2	6
Medicine graduate	5	15
Medicine student	2	6
Nurse technician licensed	10	29
Nurse technician student	1	3
No healthcare degree	1	3

Soure: The authors

About time experience performing the triage process, we can consider our sampling relatively with a good experience time, where 59% have more than three years working with triage processes in south Brazil emergency departments.

Only one participant has no practical experience at all on this survey sampling. Table 3.2 shows the respondents' experience time performing triage activities.

Table 3.2: Triage experience time of the respondents.

Triage experience time	***N***	***%***
No experience	1	3
$\leq$ 1 year	5	15
1-2 years	8	23
3-5 years	8	23
6-10 years	5	15
$\geq$ 10 years	7	21

Soure: The authors

When asked about the main healthcare unity type where the respondent worked performing triage activities, the leading unity type was the *Hospital* kind (67%), followed by Emergency Care Unit (21%). This finding can imply that the triage process, at least in this survey context, occurs mainly in big healthcare centers. Table 3.3 shows all the unity types selected by the respondents.

Table 3.3: Healthcare unity of the respondents.

Healthcare unity	***N***	**%**
Hospital	23	67
Emergency Care Unit	7	21
Basic Healthcare Unit	3	9
Ambulance	1	3

Soure: The authors

About the question where the respondent worked performing triage activities, Porto Alegre (41%) and its metropolitan area (i.e, Alvorada, Canoas, Taquara, and Viamão) (50%) was the leading region informed. We expected this finding since the researchers are from this region. Table 3.4 shows the city distributions on the survey respondents.

Table 3.4: Healthcare unity city of the respondents.

City	***N***	**%**
Porto Alegre/RS	14	41
Canoas/RS	9	26
Alvorada/RS	4	12
Viamão/RS	3	9
Santa Cruz do Sul/RS	2	6
Taquara/RS	1	3
Feliz/RS	1	3

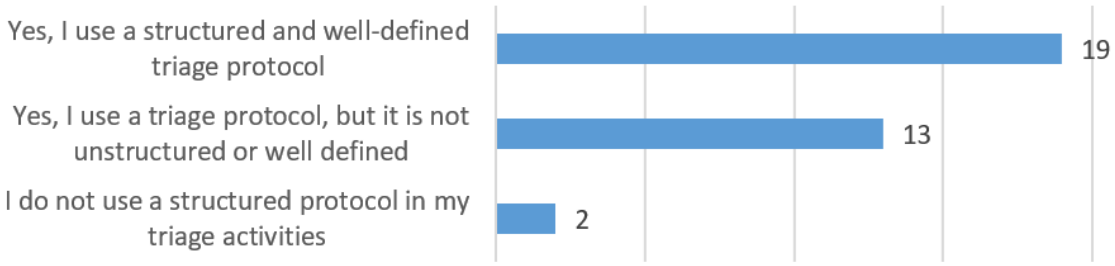
Soure: The authors

3.2.2 Triage Protocols Identification

A significant finding in this survey is the confirmation about the adoption of triage protocols in emergency departments, where almost all of our sampling uses some protocol to perform triage activities (94%). Around 56% of the participants use a *structured and well-defined* (i.e., with clear steps to follow) triage protocol, while 38% also use a protocol, but *not structured or not well-defined*.

Fig. 3.1 shows the respondents' answers about the use of triage protocols. This particular finding is important to this survey by confirming the adoption of triage protocols by healthcare professionals in a real scenario.

Figure 3.1: The use of triage protocols by the respondents.



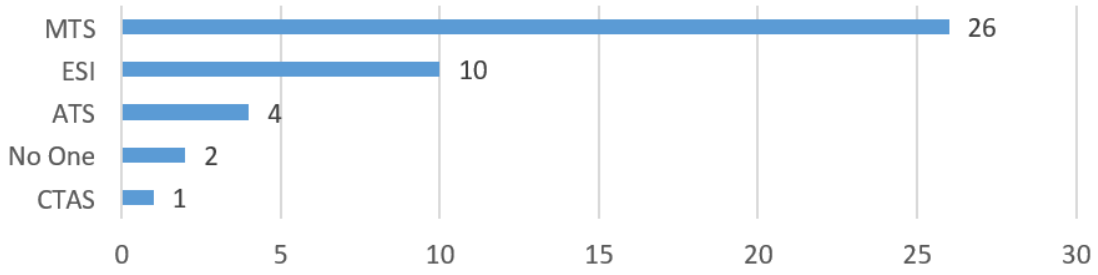
Source: The authors

About identifying the triage protocols, the MTS is the most *known* protocol (61%) by the survey respondents, followed by the ESI protocol (23%), ATS (9%), and CTAS (2%). It confirms that the four main triage protocols listed in the literature (VEEN et al., 2008; MACKWAY-JONES; MARSDEN; WINDLE, 2014) and used in this work comprehend the triage protocols knows by the respondents in this survey. This specific question was also an extra option, where the respondents could inform other triage protocols that they may know, besides the four protocols already listed. None of the 34 respondents reported another triage protocol.

When asked which triage protocol they *use* to perform their triage activities, the MTS once again was the triage protocol most assigned by the respondents, with almost half of the sampling (47%). It is interesting to observe that *customized protocols* are the second triage protocols mostly used by the respondents (35%) to perform the triage process.

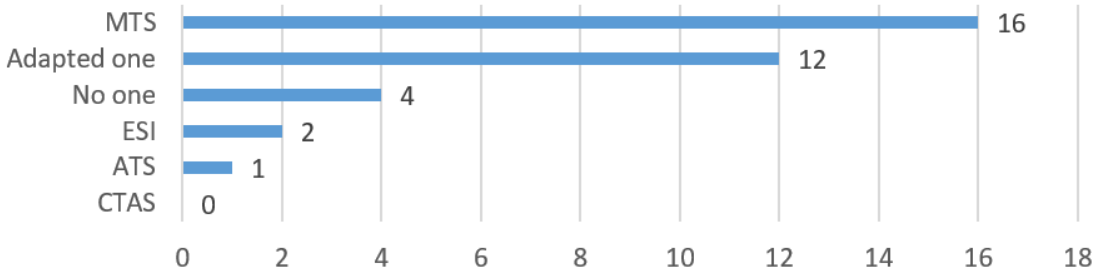
We decided to collect these two questions to specifically identify and differentiate the triage protocols the respondents know from the triage protocols the respondents use. Fig. 3.2 shows the triage protocols known by the respondents, while Fig. 3.3 shows the triage protocols used by the respondents to perform triage activities.

Figure 3.2: Triage protocols known by the survey respondents.



Source: The authors

Figure 3.3: Triage protocols used by the survey respondents.



Source: The authors

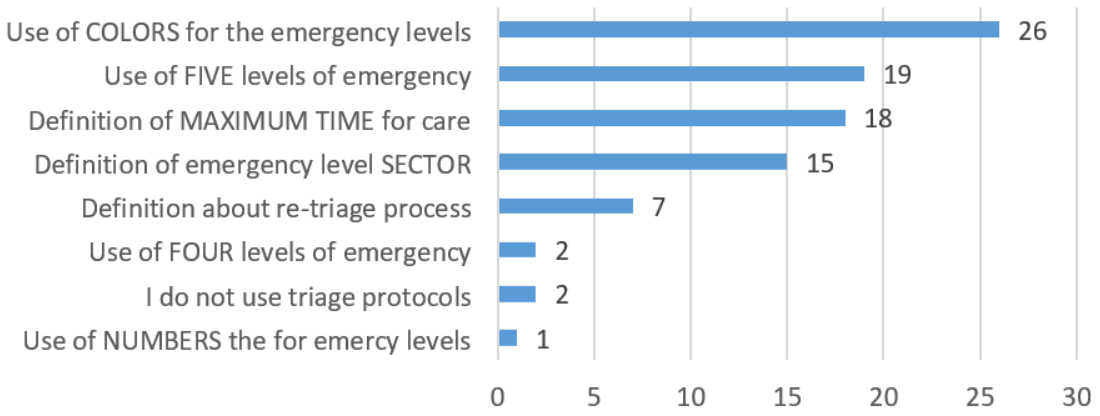
3.2.3 Triage Protocols Practical Use

When asked about the features the triage protocols that they use have, the *use of colors* was the option most selected (76%), followed by *classification in five levels* (56%) and *definition of max time to attend patients* (53%). Fig. 3.4 shows the triage protocol features used by the respondents.

In this specific question, there is the opportunity to filter the answers over who informed the use of *customized protocols* (12 respondents) on this survey. In Fig. 3.5, it is possible to observe that even in customized triage protocols, the *use of colors* still is the main feature selected, followed by *classification in five levels* (56%) and *definition of max time to attend patients*.

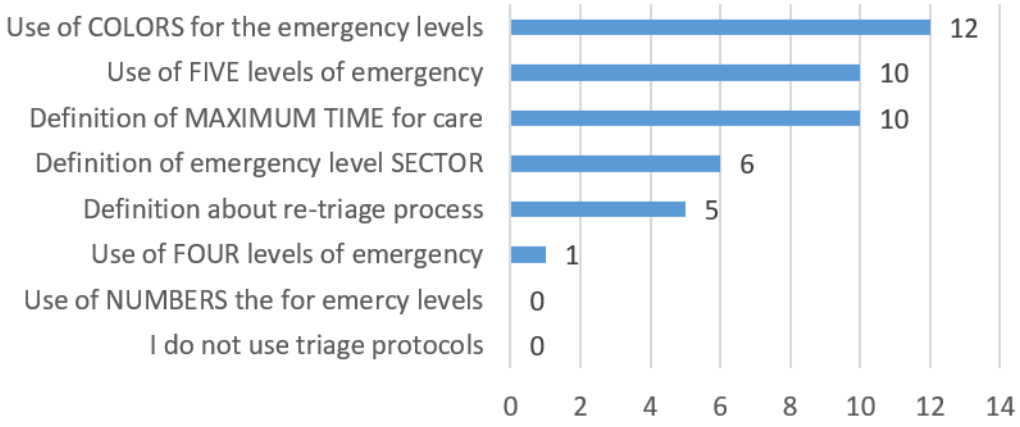
The survey respondents informed no other triage protocol features in this question.

Figure 3.4: Triage protocols features.



Source: The authors

Figure 3.5: Triage protocols features - Customized protocols



Source: The authors

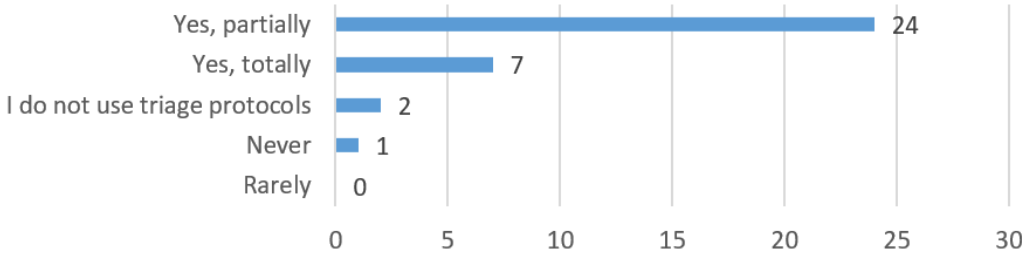
About the practical usability of the triage protocols, we asked if the triage protocol the respondents used has all the relevant information to perform their triage activities. The most selected option, around 70%, was the choice *yes, partially*. We also asked if this triage protocol is clear and easy to use in the respondents' opinion. Once again, the option *yes, partially* was the most selected in this question, with around 67%.

Although we didn't have the chance to explore which relevant information the survey respondents considered missing or in which aspect the triage protocol was not clear or easy to use, we believe that this finding is significant evidence that the current triage protocols have the opportunity for improvements in the information representation to healthcare professionals.

This finding may reinforce the difficulties conferred in some attempts to adopt or adapt the triage process in an emergency department context, mainly by keeping the focus on the patients' and nursers' needs and, at the same time, contemplate the administrative reality of each healthcare institution as proposed by Costa et al. (2015), Bellucci Júnior and Matsuda (2012).

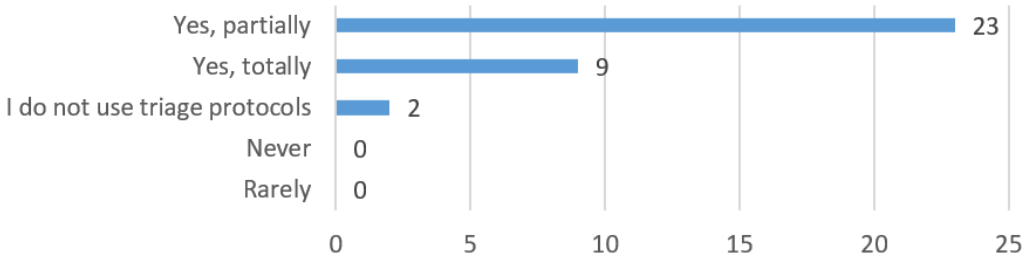
Fig. 3.6 shows the distribution of the respondents' opinions about the relevant information present in the triage protocols, while Fig. 3.7 shows the opinions about the use of the triage protocol.

Figure 3.6: The triage protocol used has all the relevant information



Source: The authors

Figure 3.7: The triage protocol used is clear and easy to use

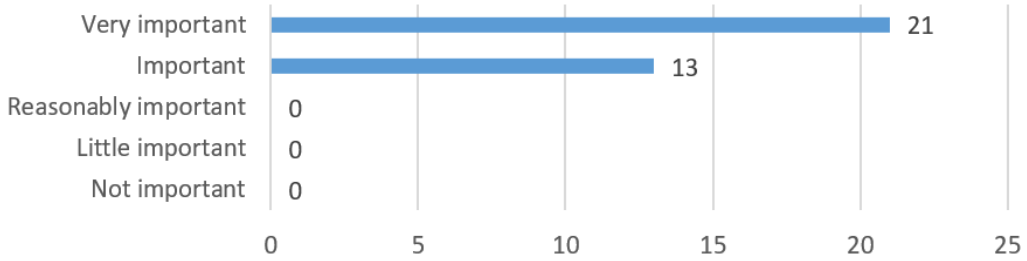


Source: The authors

Another important finding is about the importance of triage protocols. To all triage practitioners in this survey, having a triage protocol is *Important* (38%) or *Very Important* (62%) to perform triage activities.

We considered this a fundamental finding because it confirms the relevance of the triage protocols to healthcare professionals. Fig. 3.8 shows the opinions distribution about the importance of the triage protocols.

Figure 3.8: How important is the triage protocols to perform de triage activities



Source: The authors

In the last question, we asked how the triage protocol helped the participants perform the triage process. According to Gilboy et al. (2011), the purpose of triage protocol is to assure the proper resource allocation and clinical attention according to the real emergency required by an incoming patient, standardizing the evaluation method and

clinical conducts. Thus, this question was designed to understand how a triage protocol helps healthcare professionals to perform their triage activities.

In this question, there were opinions about *prioritization* as the main contribution, such in *"At the moment in the medical care where the most serious patient is treated first, regardless of having arrived after other patients less severe."*.

There were opinions about quickly access the information needed, such in *"To see quickly the steps I need to follow."* and *"To quickly and visually find the emergency level to classify the patient."*. Some respondents reported that triage protocols help to *standardize* the triage process as well, like in *"To defining steps to follow."* and *"To standardize conducts."*.

3.3 Final Considerations

Triage protocols are an essential structured tool used in emergency departments to assess and classify the patients' urgency levels. In this work, we performed a survey to investigate the use of triage protocols with healthcare professionals in the emergency departments in south Brazil.

Significant finds arose from this survey, such as the confirmation about the adoption of triage protocols, whereby 94% of the respondents use some protocol to perform triage activities in emergency departments.To all healthcare professionals in the survey, having a triage protocol is *Important* or *Very Important* to their triage activities.

We consider these fundamental findings because it validates the relevance of the triage protocols research field. Secondly, it also confirms our hypothesis H1 about the importance of triage protocols to healthcare professionals in a real scenario.

Other interesting findings emerged in this survey, such as the use of *customized protocols* as the second triage protocol mostly used, and the current protocols used by the healthcare professionals don't have all the relevant information to perform the triage activities. We consider these two findings an important evidence of the non-standard on the triage protocols and the opportunity to improve the information representation in the triage protocols.

All this set of finds supports us with enough information to guide our next step of exploring the triage protocols' aspects through a process-oriented approach and generate the triage protocols process models and description with BPM.

4 TRIAGE PROTOCOL MODEL DESIGN

After applying the first survey and considering its findings, we consider that we have a reasonable set of evidence to confirm our first hypothesis about the importance of triage protocols to healthcare professionals perform their triage activities.

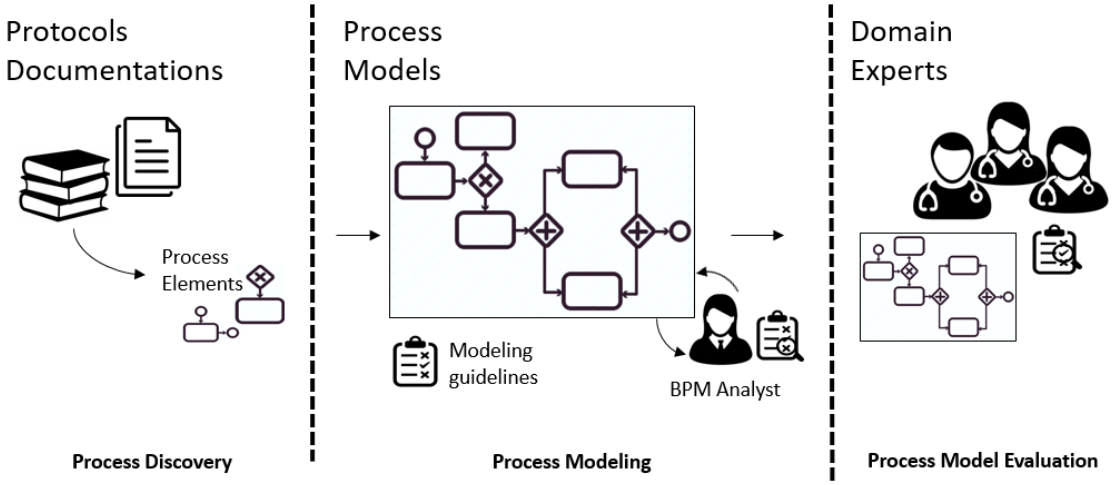
Additionally, we collected relevant information about the aspects of a non-standardization of the triage protocols used by the respondents, such as using adapted protocols to perform the triage process, including that the triage protocols have only partially all the relevant information to perform the triage activities. To address these issues, we explore the triage protocols' aspects through process-oriented approach conducting a BPM Process Discovery.

Fig. 4.1 illustrates our process model approach. We use the Protocols Documentations as the main input to our Process Discovery phase. In this step, we extract the process elements (EPURE et al., 2015) through the business document analysis. To generate the triage Process Models, we used a systematic approach of Process Modeling, following a set of modeling guidelines to meets different quality criteria. In addition, we validated our Process Models with a BPM Analyst to improve the syntactic quality aspect.

Finally, we performed a new survey (detailed in Chapter 5) inviting Domain Experts (i.e., healthcare professionals with triage experience) to perform an individual interview and evaluate our triage protocol process models, as detailed in Chapter 6.

The Process Discovery and the Process Modeling steps (and the Process Models) are better detailed as follows. The Process Model Evaluation with the Domain Experts is detailed in Chapter 6.

Figure 4.1: Our process model approach



Source: The authors

4.1 Process Discovery

Process discovery is defined as the act of collecting information about an existing business process and structured it in terms of a process model. There are different ways to access information about a process within a business context, such as the interviewing process participants or examining how the process occurs in practice. The method used in this work to perform a triage protocol process discovery and extract the process models is the evidence-based method through document analysis (i.e., a textual description of the business process) (DUMAS et al., 2018; MENDLING; NEUMANN; AALST, 2007) of the triage protocol implantation guidelines.

For each protocol, we got the official process documentations when it is possible. For example, in the MTS triage protocol, we used the official implantation guideline maintained by the Manchester Triage Group (MACKWAY-JONES; MARSDEN; WINDLE, 2014). In the ATS triage protocol, we used the "Emergency Triage Education Kit" provided by the Department of Health and Ageing from the Australian Government (HEALTH; AGEING, 2009c; HEALTH; AGEING, 2009a; HEALTH; AGEING, 2009b).

The advantage of document analysis is that we can use the available business documentation to familiarize ourselves with parts of the triage process and its reality in emergency departments. This method is also beneficial in our work because it will help us at the moment of talking to domain experts to evaluate the process models.

This discovery process method also faces some challenges. Usually, the available documentation about a process in a specific business context is not organized in a process-oriented way, and the level of granularity of the business documentation might not be appropriate to extract a process model. We believe that consulting four different business documentation from different sources (i.e., the triage protocols guidelines) about the same business process (i.e., the triage process per se) could help us get different points of view and address these challenges.

Another challenge in this method is that a business document is usually only partially accurate or does not reflect the business process reality. We believe the next survey step, the process model evaluation by the healthcare professionals, also can address this challenge.

In the following section, we report the process modeling approach from the step of document analysis.

4.2 Process Modeling

To extract the process elements from a business document and compose a process model, we followed a predefined procedure to approach this activity in a systematic way. We followed the five steps of the process modeling method proposed by (DUMAS et al., 2018):

(I) Identify the process boundaries: In this first modeling step, we identify the boundaries of this process from the perspective of who executes the triage process. In this context, the triage practitioner (i.e., usually a nurse). In this step, it is also necessary to identify the events that trigger the process's start and those that indicate its conclusion.

(II) Identify activities and events: The goal of the second modeling step is to identify the main process activities and intermediate events. It is also necessary to identify the events that happen along the process that will derivates intermediate events in the process model. Due to the number of assessment activities and evaluations over an incoming patient, this step generated the major number of triage process elements compared to the others modeling steps.

(III) Identify resources and their handoffs: Once identified the set of primary activities and the intermediate events, it is necessary to identify the activities' owners. This step provides the base for the determination of pools and lanes.

(IV) Identify the control flow: In this modeling step, it is necessary to identify the order dependencies, decision points, parallel execution of activities and events, and potential repetition. In this phase, the decision points (e.g., the decision on if the patient needs an immediate intervention) are formalized in XOR-splits, and the parallel independent activities (e.g., assess the patient circulation condition and assess the patient breathing condition) are formalized in AND-splits.

(V) Identify additional elements: Finally, in this last modeling step, we complement the process model with the involved business objects, such as appending data objects and text annotations, with their connections to activities or events by data associations.

In the following section, we report our approach to addressing the quality aspects over the triage process modeling activity.

4.3 Process Model Quality

During the activity of document analysis and transformation of the process elements into a process model, it is essential to assure that the model is syntactically correct and meets different quality criteria, establishing trust in the process model.

To achieve a syntactic quality, we follow the specifications of the BPMN 2.0 (OMG, 2013), observing the structural and behavioral syntactic rules proposed by Dumas et al. (2018). We also evaluated our Process Models with a BPM Analyst as a way to ensure the syntactic quality aspect. We also evaluated our Process Models with a BPM Analyst as a way to ensure the syntactic quality aspect.

To achieve a pragmatic quality in this phase, we follow the 7PMGs proposed by Mendling, Reijers and Aalst (2009) during the activity of composing the triage protocols process models. In this aspect, we highlight two specifics issues related to the process modeling guidelines.

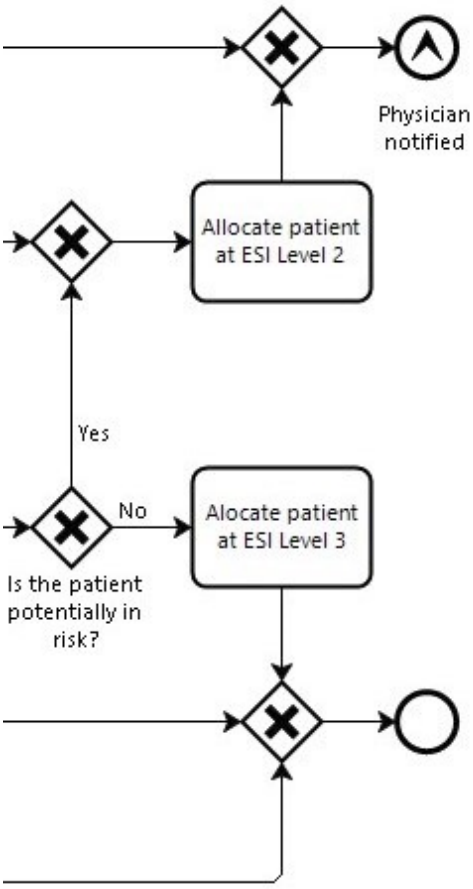
Fisrt, in the ESI process model, we used two End Events to represent the final process state: a *Standard End Event* to finish the main triage process (as used in the process models of the other three triage protocols); and an *Escalation End Event* as a way to specify the escalation of the process to a higher level of clinical responsibility. Fig. 4.2 illustrates the ESI Process Model fragment with two Ends Events.

According to its protocol documentation (GILBOY et al., 2011), it is mandatory to notify the physician in the higher urgency categories (i.e., ESI Level 1 and ESI Level 2). We decided to keep this process distinction to maintain the orientation according to the original process documentation.

This specific modeling decision may infringe the guideline G3 (i.e., *use one start and one end event*). According to this guideline, the number of start and end events is directly connected with an increase in error probability (MENDLING; NEUMANN; AALST, 2007; MENDLING; REIJERS; AALST, 2009), requiring a single start and end node (W. van der Aalst, A. ter Hofstede, B. Kiepuszewski, 2003; MENDLING; REIJERS; AALST, 2009) to generated a process model that is easier to understand and allow all kinds of analysis. Despite this orientation, we believe that our modeling decision to distinguish the two kinds of end events does not affect the ESI process model pragmatic quality.

The second issue is related to the ATS protocol. In this model, we represented four triage assessment activities coming from an OR-split gateway and connecting in an OR-join gateway.

Figure 4.2: ESI Process Model fragment with two Ends Events



Source: The authors

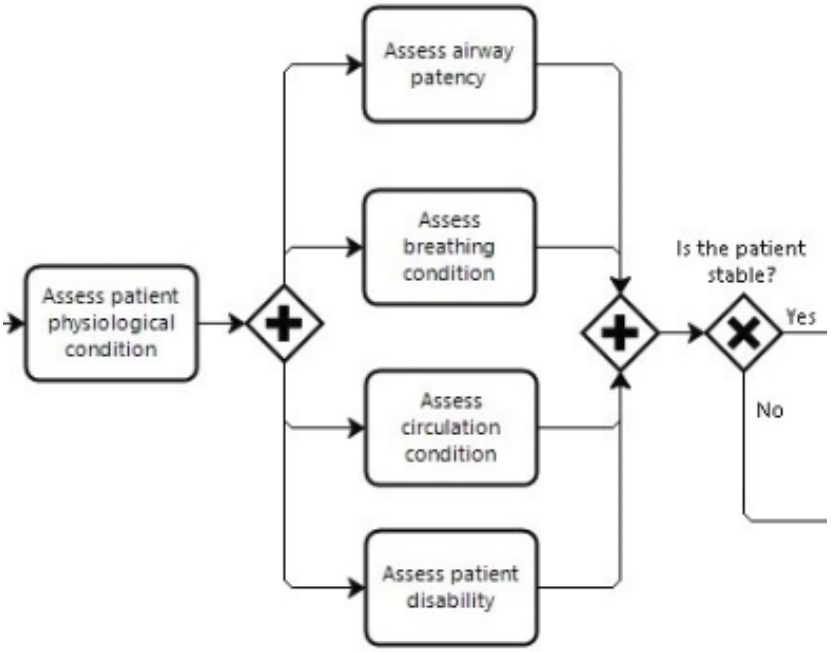
According to its protocol documentation (HEALTH; AGEING, 2009c), all four patient assessment activities must be executed in the triage process, however, there is no specific order to execute this set of evaluations. We also decided to keep these parallel activities in order to maintain the original process orientation. Fig. 4.3 illustrates the ESI Process Model fragment with the parallel activities.

This specific modeling decision may infringe the guideline G5 (i.e., *avoid OR routing elements*). According to this guideline, process models with only AND and XOR gateways connectors are less susceptible to errors (MENDLING; NEUMANN; AALST, 2007; MENDLING; REIJERS; AALST, 2009).

Moreover, there are some ambiguities in the OR-join semantics leading to mistakes, and implementation problems (KINDLER, 2006; FERRARI et al., 2018; MENDLING; REIJERS; AALST, 2009).

In this issue, we also believe that our modeling decision to maintain the four parallel assessment activities in an OR-split/OR-join gateways does not affect the ATS process model pragmatic quality.

Figure 4.3: ATS Process Model fragment with parallel activities



Source: The authors

Another important aspect observed during the modeling phase was the generation of the triage protocol process models without ambiguous sentences (SILVA et al., 2018; AA, 2018; AKBAR; BAJWA; MALIK, 2013) as a way to improve the process model pragmatic quality.

4.4 Triage Protocol Process Model and Description

In this section, we report and detail our Triage Protocols Process Model proposals and its process description on the four main triage protocols studied in this work. In addition, we highlight the formal document or source used to extract de process elements to each triage protocol model.

4.4.1 Manchester Triage System

To extract the MTS process elements and compose de process model in BPMN, we used the official implantation guideline maintained by the *Manchester Triage Group* (MACKWAY-JONES; MARSDEN; WINDLE, 2014) as business process documentation.

Since the MTS has 55 specifics flowcharts to different clinical situations, we choose a specif one to extract the emergency discriminators to the process model. Considering that chest pain is a common complaint, setting around 2% to 5% of all the patients that seek an emergency department (MACKWAY-JONES; MARSDEN; WINDLE, 2014), we considered an incoming patient with a *chest pain* complaint in this model. Fig. 4.4 illustrates the MTS process model in BPMN notation.

Process Description: This triage process is executed by a *triage practitioner* and starts when a patient arrives in the Emergency Department (Event: *Patient arrived in the Emergency Department*).

The triage practitioner's first step is to identify the patients' health problem, considering the main chief complaint, sign, or symptom presented by the patient or a relative (Activity: *Identify the patients' health problem*). This first part of the MTS triage process is when the practitioner selects the corresponding flowchart according to the patient's complaint.

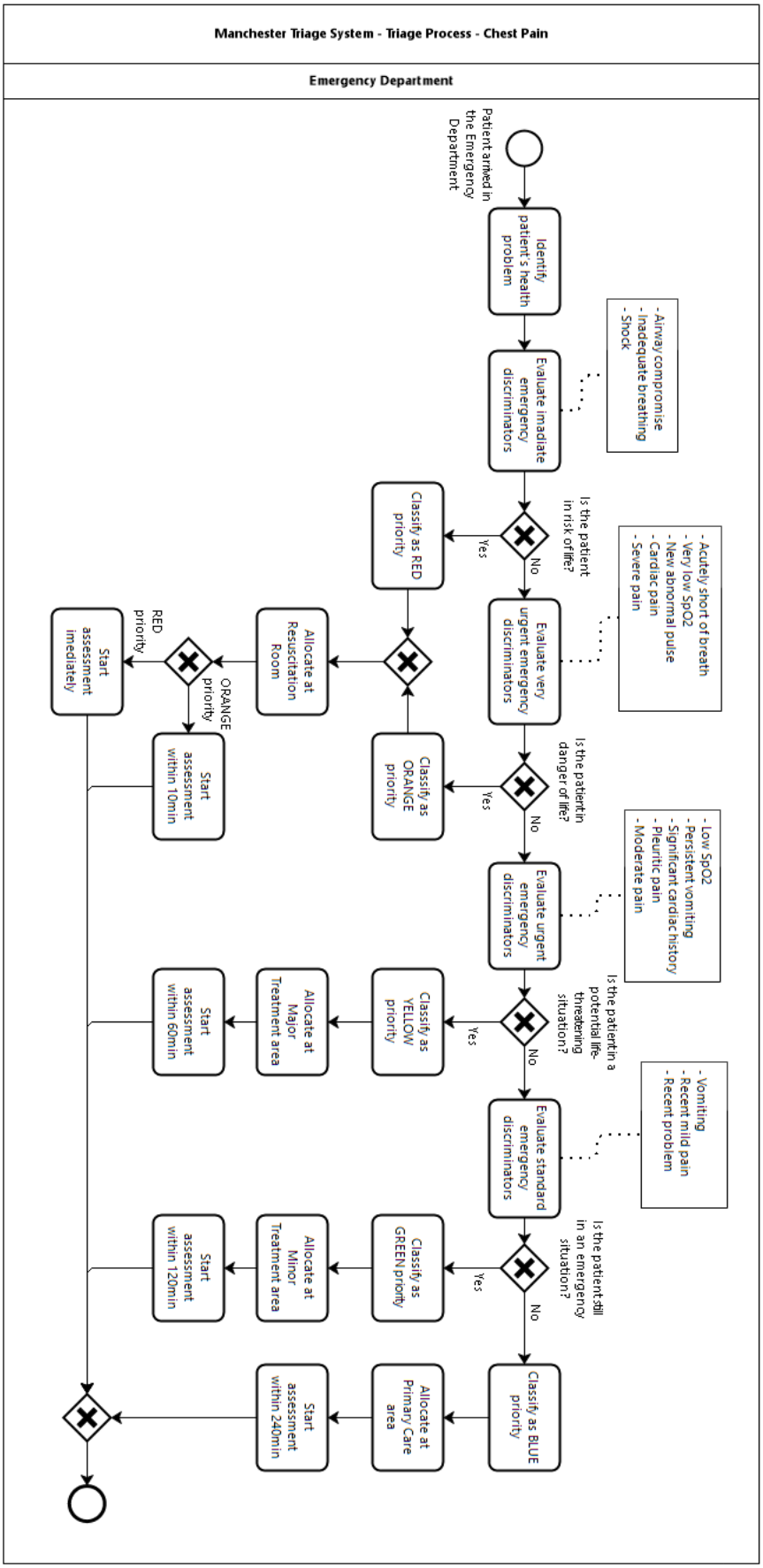
The flowcharts facilitate quick assessment by suggesting structured indicators that must be evaluated according to the patient's urgency level. Table 2.3 shows a list of all 55 flowcharts/situations available in the Manchester Triage System. Each chart identifies discriminators that allow the triage practitioner to determine the patient's clinical priority quickly.

Once the appropriate flowchart has been chosen, the triage practitioner must evaluate the immediate emergency discriminators (i.e., airway compromise, inadequate breathing, shock) assessing the patients' emergency level (Activity: *Evaluate immediate emergency discriminators*). The emergency discriminators are represented in the process model with the *Text Annotation* element connected to its correspondent evaluation *Activity*.

Considering the immediate emergency discriminators, the triage practitioner must classify in the RED priority if the patient is at risk of life (Activity: *Classify as RED priority*). Next, the triage practitioner must allocate the patient to the Resuscitation Room (Activity: *Allocate at Resuscitation Room*) to immediately start the assessment without wasting time (Activity: *Start assessment imediately*). In this scenario, the triage process is considered finished.

Supposing the patient meets the very urgent emergency discriminators (Activity: *Evaluate very urgent emergency discriminators*), which means that patient is in danger of life, the triage practitioner must classify the patient in the ORANGE priority (Activity: *Classify as ORANGE priority*) and then allocate the patient at the Resuscitation Room

Figure 4.4: The MTS process model in BPMN notation



(Activity: *Allocate at Resuscitation Room*) to start the assessment within 10min at least (Activity: *Start assessment within 60min*).

If the patient is under a potentially life-threatening situation, in that case, the triage practitioner must classify in the YELLOW priority (Activity: *Classify as YELLOW priority*) and then allocate the patient to the Major Treatment area (Activity: *Allocate at Major Treatment area*) to start assessment in a maximum 60min (Activity: *Start assessment within 60min*).

Supposing that the patients' situation is less urgent, the triage practitioner must classify in the GREEN priority (Activity: *Classify as GREEN priority*) and then allocate the patient to the Minor Treatment area (Activity: *Allocate at Minor Treatment area*). The patient assessment must start within 120min (Activity: *Start assessment within 120min*).

A non-urgent condition leads to a BLUE priority classification (Activity: *Classify as BLUE priority*), where the patient must be allocated at the Primary Care area (Activity: *Allocate at Primary Care area*), and, after that, the assessment should start within 240min (Activity: *Start assessment within 240min*).

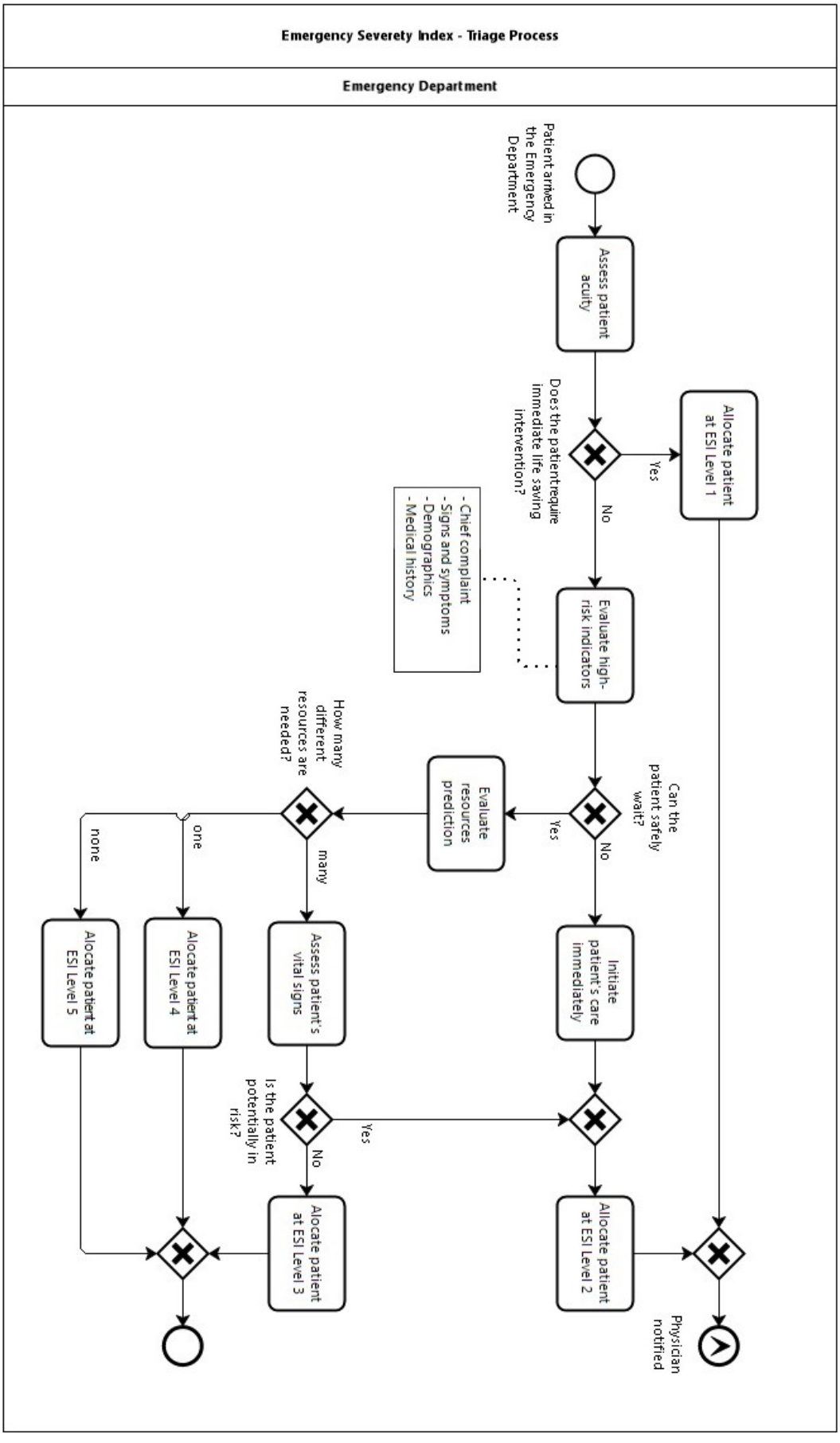
4.4.2 Emergency Severity Index

To extract the ESI process elements and compose de process model in BPMN, we used the fourth version of the ESI Implantation Handbook (GILBOY et al., 2011) maintained by the American government *Agency for Healthcare Research and Quality* as business process documentation. Fig. 4.5 illustrates the ESI process model in BPMN notation.

Process Description: This triage process is executed by a *triage nurse* and starts when a patient arrives in the Emergency Department (Event: *Patient arrived in the Emergency Department*). The triage nurse must quickly assess the patients' acuity (Activity: *Assess patient acuity*) and then ask, "does this patient require immediate life-saving intervention?". If the answer is "yes," the triage nurse must immediately allocate the patient at ESI Level 1 (Activity: *Allocate patient at ESI Level 1*). In this case, the process ends with the notification to the physician about the incoming patient (Event: *Physician notified*).

To assess the patient's level of responsiveness, the triage nurse can use the AVPU scale: a patient who scores P (pain) or U (unresponsive) on the AVPU scale should also be triaged ESI level 1. Patients classified as ESI level 1 must be treated immediately because the timeliness of interventions can affect morbidity and mortality. This condition requires

Figure 4.5: The ESI triage process in BPMN notation



immediate physician evaluation and intervention.

Once the triage nurse has determined the patient does not meet the criteria for ESI level 1, the triage nurse needs to evaluate high-risk indicators (Activity: *Evaluate high-risk indicators*) to decide whether this patient is in a situation that should not wait to be seen.

An experienced triage nurse must assess the patient's chief complaint, the presenting signs and symptoms, the demographics data, and medical history to identify a high-risk situation. These high-risk indicators are represented in the process model with the *Text Annotation* element connected to its correspondent evaluation *Activity*.

If the patient should not wait, the triage nurse must immediately initiate the patient's care (Activity: *Initiate patient's care immediately*) to allocate the patient at ESI Level 2 (Activity: *Allocate patient at ESI Level 2*). At this point, the physician also is notified about the incoming patient. While ESI triage protocol does not suggest specific time intervals, ESI level-2 patients remain a high priority, so allocation and treatment should be initiated immediately. A vital orientation is that the emergency nurse should start care even without a physician at the bedside.

In case the patient can wait, the triage nurse must evaluate resource prediction (Activity: *Evaluate resources prediction*), which means assessing how many different resources the patient is going to consume for the physician to reach a disposition decision (i.e., admission, discharge, or transfer). Table 4.1 provides a general guidance on the types of diagnostic tests, procedures, and treatments that constitute a resource in the ESI triage process.

If the patients require many resources, the nurse needs to assess the patient's vital signs (Activity: *Assess patient's vital signs*). If they are outside the accepted parameters, the triage nurse should consider allocating the patient at ESI Level 2 once the patient can be potentially at risk of life.

The vital signs used are pulse rate, respiratory rate, oxygen saturation, and, for any child under age 3, body temperature. Table 4.2 shows the parameters for danger zone vital signs.

Table 4.1: General guide for ESI resource

Resources	**Not resource**s
- Computed tomography, magnetic resonance imaging, ultrasound angiography - Electrocardiogram , X-rays - Labs (blood, urine)	- History and physical (including pelvic) - Point-of-care testing
- Intravenous fluids (hydration)	- Saline or heplock
- Intravenous, intramuscular or nebulized medications	- Medications through oral administration - Tetanus immunization - Prescription refills
- Specialty consultation	- Phone call to the Primary Care Physician
- Simple procedure = 1 (lac repair, Foley cath) - Complex procedure = 2 (conscious sedation)	- Simple wound care (dressings, recheck) - Crutches, splints, slings

Soure: Adapted from (GILBOY et al., 2011)

If many resources are needed, but the vital signs are stable, the patient can be allocated at ESI Level 3 (Activity: *Allocate patient at ESI Level 3*). If just one resource is required, the patient can be assigned at ESI Level 4 (Activity: *Allocate patient at ESI Level 4*). If no resource is required, the patient should be allocated at ESI Level 5 (Activity: *Allocate patient at ESI Level 5*).

Table 4.2: Danger Zone Vital Signs

Age	**Heart Rate**	**Respiratory Rate**	**Oxygen Saturation**
< 3 month	> 180 bpm	> 50 bpm	< 92%
3 month - 8 years	> 160 bpm	> 40 bpm	< 92%
3 to 8 years	> 140 bpm	> 30 bpm	< 92%
> 8 years	> 100 bpm	> 20 bpm	< 92%

Soure: Adapted from Gilboy et al. (2011)

4.4.3 Canadian Triage Acuity Scale

To extract the CTAS process elements and compose de process model in BPMN, we used the CTAS Implementation Guidelines (BEVERIDGE et al., 1998) maintained by the *Canadian Association of Emergency Physicians* and the *National Emergency Nurses Affiliation of Canada* as business process documentation. Fig. 4.6 illustrates the CTAS process model in BPMN notation.

Process Description: This triage process is executed by a *triage nurse* and starts when a patient arrives in the Emergency Department looking for help (Event: *Patient arrived in the Emergency Department*). As soon as a patient comes into the emergency department, the triage nurse should take a critical first look to assess the patient's health problem (Activity: *Take a critical first look*) by applying a quick "ABCD" check (Airway, Breathing, Circulation, Disability neurological). The "ABCD" check is represented in the process model with the *Text Annotation* element connected to its correspondent evaluation *Activity*.

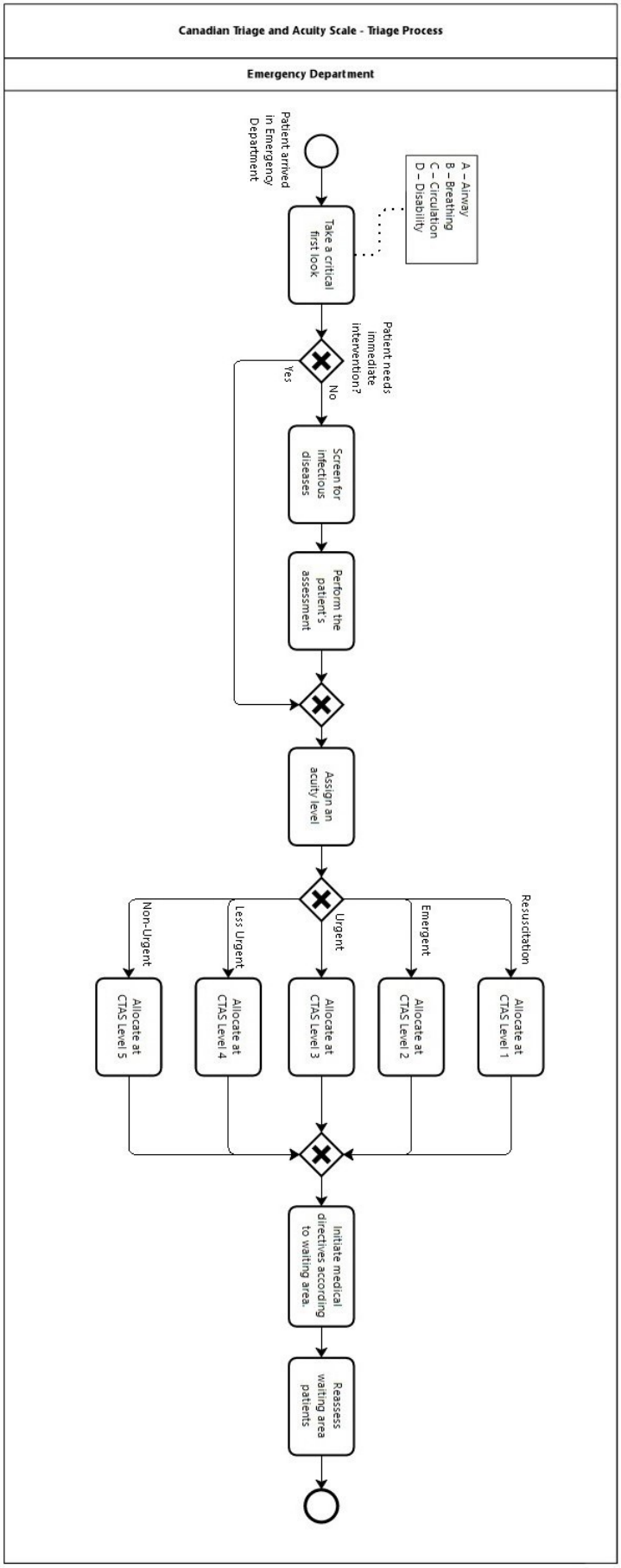
Suppose the triage nurse does not identify an immediate need for intervention. In that case, the triage nurse must first screen the patient for infectious diseases (Activity: *Screen for infectious diseases*) and then perform the patients' assessment (Activity: *Perform the patients' assessment*). This activity helps determine patient acuity levels by drawing on observable clinical signs (e.g., wounds, rashes, bleeding, cough). Considering the critical first look and the patient's assessment as performed, the triage nurse must assign an acuity level (Activity: *Assign an acuity level*).

In this activity, the triage practitioner must consider all the incomes from the critical first look step, the primary patient's complaint (including the history), and measurement of vital signs. It is appropriate to respect an assessment's time limit, depending on the initial impression's severity.

When the patient is under conditions considered threats to life or imminent risk of deterioration (i.e., when it requires aggressive interventions), the triage nurse should quickly allocate at CTAS Level 1 (Activity: *Allocate at CTAS Level 1*) to immediately start the treatment. Patients under this condition usually present undeniable signs of distress and unstable vital signs.

When the patient is in conditions that are a potential threat to life, limb, or function (i.e., requiring prompt medical intervention by the physician or medical staff), the triage nurse should allocate at CTAS Level 2 (Activity: *Allocate at CTAS Level 2*). It is essential

Figure 4.6: The CTAS triage process in BPMN notation



to provide immediate medical attention in this situation since patients classified as CTAS Level 2 can quickly deteriorate their clinical condition, requiring resuscitation.

In conditions that could potentially progress to a severe problem requiring emergency intervention, the triage nurse should allocate the pátients at CTAS Level 3 (Activity: *Allocate at CTAS Level 3*). In this situation, vital signs are usually regular or at the normal range's upper and lower edges.

In conditions related directly to the patient's age, distress, or that is potential for clinical deterioration (and probably would benefit from intervention or reassurance within one or two hours), the triage nurse should allocate the patient at CTAS Level 4 (Activity: *Allocate at CTAS Level 4*).

Finally, when there are conditions that may be acute but non-urgent or conditions that may be part of a chronic problem with or without evidence of deterioration, the triage nurse should allocate at CTAS Level 5 (Activity: *Allocate at CTAS Level 5*).

After a proper triage classification, the triage nurse should initiate the medical directives according to the waiting area (Activity: *Initiate medical directives according to the waiting area*). Since a patients' condition can deteriorate anytime, the triage nurse must reassess waiting area patients continually (Activity: *Reassess waiting area patients*).

The reassessment's intensity depends upon the presenting complaint, the initial triage level, and any changes indicated by the patient or identified by the triage nurse.

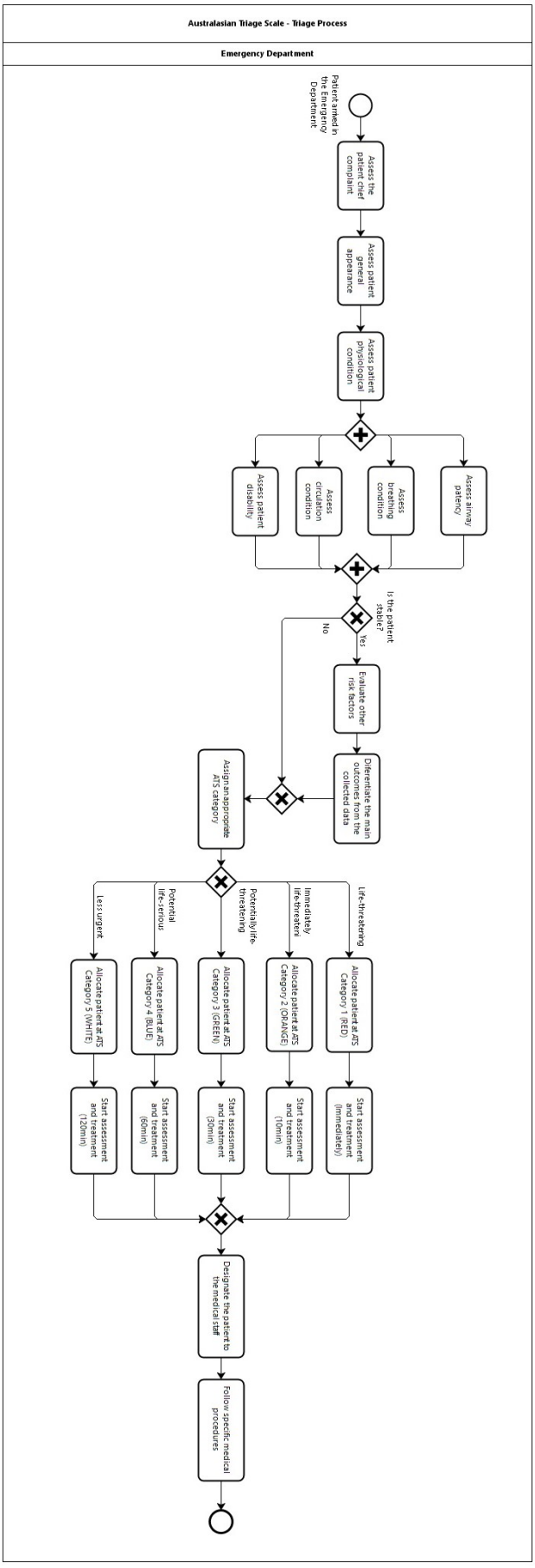
4.4.4 Australasian Triage Scale

To extract the ATS process elements and compose de process model in BPMN, we used the "Emergency Triage Education Kit" (HEALTH; AGEING, 2009c; HEALTH; AGEING, 2009a; HEALTH; AGEING, 2009b) maintained by the *Department of Health and Ageing* from the Australian Government as business process documentation. Fig. 4.7 illustrates the ATS process model in BPMN notation.

Process Description: This triage process is executed by a *triage nurse* and starts when a patient arrives in the Emergency Department looking for help (Event: *Patient arrived in the Emergency Department*). The triage nurse must first assess the patients' chief complaint (Activity: *Assess the patient chief complaint*), and then assess the patients' general condition (Activity: *Assess patients general appearence*). Both steps should take seconds.

After this first assessment, the triage nurse should assess the patients' physiological

Figure 4.7: The ATS triage process in BPMN notation



condition (Activity: *Assess patient physiological condition*) to begin the primary survey and identify the patient's life-threatening situation. Table 4.3 provides a summary of adult physiological discriminators for the ATS classification.

Table 4.3: Summary of adult physiological predictors for the ATS

	Category 1 Immediate	**Category 2 10 min**	**Category 3 30 min**	**Category 4 60 min**	**Category 5 120 min**
Airway	Obstructed, partially obstructed	Patent	Patent	Patent	Patent
Breathing	Severe respiratory distress, absent respiration, hypoventilation	Moderate respiratory distress	Mild respiratory distress	No respiratory distress	No respiratory distress
Circulation	Severe haemodynamic, absent circulation, haemorrhage	Moderate haemodynamic compromise	Mild haemodynamic compromise	No haemodynamic compromise	No haemodynamic compromise
Disability	GCS < 9	GCS 9–12	GCS > 12	Normal GCS	Normal GCS

Soure: Adapted from Health and Ageing (2009c)

The primary survey applied by the triage nurse consists of the following steps: *Assess patient physiological condition*: The triage nurse always has to check the patient's airway for patency, considering cervical spine precautions where indicated (Activity: *Assess patient physiological condition*).

Assess breathing condition: This activity determines the respiratory rate and the patient's breathing work. It is essential to detect hypoxemia conditions, for example, using pulse oximetry (Activity: *Assess breathing condition*). *Assess circulation condition*:

The circulation assessment determines heart rate, pulse and pulse characteristics, skin indicators, and oral intake and output. It is essential to detect hypotension during the triage assessment to facilitate early and aggressive intervention (Activity: *Assess circulation condition*).

Assess patient's disability: This assessment includes determining the AVPU scale, GCS and/or neurological activity, assessing consciousness loss level, and pain assessment (Activity: *Assess patient's disability*). An altered level of consciousness is a crucial indicator of the risk for severe illness or injury. This set of four assessment activities must be done to evaluate the patient's life-threatening situation, but there is no particular execution order.

After the primary survey and if the patient's condition is considered stable by the triage nurse, it is necessary to evaluate other risk factors (Activity: *Evaluate other risk factors*) such as temperature (hypothermia and hyperthermia), extremes of age (very young or very old), patient's illness history, history of violence and trauma. The triage nurse must differentiate the principal outcomes from the collected data (Activity: *Differentiate the main outcomes from the collected data*) to a correct emergency classification. The presence of a physiological abnormality, a failure to recognize and treat it, and age greater than 65 years are known as risk factors for poor outcomes that could lead to an incorrect triage classification.

Once all critical information about the patients' condition is collected, the triage nurse must assign an appropriate ATS category urgency level (Activity: *Assign appropriate ATS category*) according to the clinical assessment done. When the patient is under a life-threatening situation (or imminent risk of deterioration), the triage nurse must allocate the patient at ATS Category 1 (Activity: *Allocate the patient at ATS Category 1 (RED)*) to start the assessment and the treatment immediately (Activity: *Start assessment and treatment (immediately)*).

When the patient is under an immediately life-threatening condition, the triage nurse must allocate the patient at ATS Category 2 (Activity: *Allocate the patient at ATS Category 2 (ORANGE)*) to start the assessment and treatment within 10min (Activity: *Start assessment and treatment (within 10min)*).

When the patient is under a potentially life-threatening or critical time-critical treatment or severe pain condition, the triage nurse must allocate the patient at ATS Category 3 (Activity: *Allocate the patient at ATS Category 3 (GREEN)*) to start the assessment and treatment within 30min (Activity: *Start assessment and treatment (within*

30min)).

In case the patient is under a potential life-serious or situational urgency or significant complexity condition, the triage nurse must allocate the patient at ATS Category 4 (Activity: *Allocate the patient at ATS Category 3 (BLUE)*) to start the assessment and treatment within 60min (Activity: *Start assessment and treatment (within 60min)*).

When the patient is under a less urgent situation, requiring no urgent intervention, the triage nurse must allocate the patient at ATS Category 5 (Activity: *Allocate the patient at ATS Category 5 (WHITE)*) to start the assessment and treatment within 120min (Activity: *Start assessment and treatment (within 120min)*).

After the patients' ATS category is determined, the triage nurse must designate the patient to the medical staff (Activity: *Designate the patient to the medical staff*), including a brief handover about the patient's clinical condition.

By the last, the medical staff should proceed with the Emergency Department model of care to treatment after the triage process (Activity: *Follow specific medical procedures*).

4.5 Final Considerations

In this chapter, we presented our process modeling approach and the triage protocol process modeling and description proposals. We considered the protocol implantation guidelines as the principal source to extract the information we need to perform the process models.

It is important to highlight that we tried to keep the original terms according to the guideline used. For example, according to the MTS protocol, the person who executes the triage activities is referenced as "*triage practitioner*", while in the other protocols is referenced as "*nurse*" only.

By generating these visual and description documentations of the triage protocol process through a process-oriented approach with BPM, we consider our first goal as achieved.

Chapter 5 presents the second survey we performed to invite Domain Experts to evaluate our triage protocol process modeling and description proposals.

5 SECOND SURVEY

After performing a process modeling on the triage guidelines and generating the four Triage Protocol Process Model and Descriptions using a BPM approach (G1), we intended to evaluate with healthcare professionals the process models' adherence to the real triage process (G2). This specific goal also allows us to confirm or improve the process model semantic quality aspect.

By achieving the second goal with the domain experts, it is possible to evaluate the expression strength of BPMN to represent triage processes by observing how much the healthcare professionals understand the Triage Protocol Process Model, including its process elements and components. This specific second goal also allows us to achieve a pragmatic quality over the process model and, mainly, verify this works' second hypothesis (H2);

To achieve these purposes, we performed a second online survey inviting healthcare professionals to perform an individual meeting and evaluate our process models. This survey and the interview selection are better detailed as follows.

5.1 Survey Aplication

To reach healthcare professionals and evaluate our process models, we elaborated a new quantitative survey. This online questionnaire was composed of ten objective questions divided into four specific sessions.

This first session was an introductory message about the academics researchers and the survey objective as the first questionnaire. We also highlighted that no personal information would be collected during the survey. In this questionnaire first session, we also collected data related to the respondent's profile. Since we did not collect any personal identification on the first survey, we basically collected the same respondent's profile information on this second survey: (i) academics degree; (ii) experience time performing triage; (iii) the healthcare unity type where the respondent has worked; (iv) the city of this healthcare unity.

Since the MTS and ESI models were the most known triage protocol indicated by the participants on our first survey, this second and third questionnaire sessions focused on these two protocols. In these sessions, we collect information about the respondents' knowledge of the MTS and ESI triage protocols.

First, in the second session, we presented a textual description of the MTS with one of its flowcharts as an explanatory topic about this protocol. Then, the respondents were asked to select their knowledge level on this protocol (i.e., very good, good, acceptable, poor, very poor) and then inform where they considered achieving this knowledge, if in the college, a specific training course, books, or at professional work.

In the third session, we presented a similar question in the same model but with the ESI protocol. An additional question was added by the end of this session, asking respondents to inform other triage protocols if they also have theoretical or practical experience, such as the ATS, CTAS, or even another protocol.

In the last session, we invited the respondent to participate in our next survey step, where we would perform an individual interview to discuss the practical use of triage protocols in emergency departments. The complete questionnaire applied with all the questions is attached to this work in Appendix B.

This second study was available online from 28 April to 10 May 2020. As the first survey, we used convenience sampling to invite the participants, where the online survey link was sent by e-mail to the researcher's contacts network. In addition, we also published a call for participation in different social media (e.g., Facebook, Twitter).

5.2 Survey Analysis

This second survey involved a total of 31 participants from Brazils' south region that answered our online questionnaire. The analysis in this session will be over all these 31 participants.

5.2.1 Demographic Information

About the respondent's academics degree, this new sampling was predominantly *Nursing graduate* (48%) and *Nurse technician licensed* (39%). In contrast, in this second survey, we have only participants from the Nursing field, without participants from the Medicine field (student or graduated) as in the first survey. Table 5.1 shows all the respondents' academics degrees on this second survey.

Table 5.1: Education degree of the respondents.

Education degree	***N***	***%***
Nursing graduate	15	48
Nurse technician licensed	12	39
Nursing student	3	10
Nurse technician student	1	3

Soure: The authors

About time experience performing the triage process, this sampling was less triage experienced than the first survey. However, we still consider our sampling relatively with a good experience time, where 45% of the respondents have more than three years working with triage processes. At this time, about 10% of the survey respondents has no practical experience at all. Table 5.2 shows the respondents' experience time performing triage activities.

Table 5.2: Triage experience time of the respondents.

Triage experience time	***N***	***%***
No experience	3	10
$\leq$ 1 year	8	26
1-2 years	6	19
3-5 years	5	16
6-10 years	4	13
$\geq$ 10 years	7	21

Soure: The authors

In the question about the main healthcare unity type where the respondent worked performing triage activities, the results were similar to the first survey. The leading unity type was the Hospital kind (64%), followed by Emergency Care Unit (8%). Table 5.3 shows the healthcare unity type distribution.

Table 5.3: Healthcare unity of the respondents.

Healthcare unity	***N***	***%***
Hospital	20	64
Emergency Care Unit	8	26
Basic Healthcare Unit	3	10

Soure: The authors

About the question where the respondent worked performing triage activities, Porto Alegre (32%) and its metropolitan area (i.e, Alvorada, Cachoeirinha, Campo Bom, Canoas, Gravataí and Sapucaia do Sul) (39%) was the leading region informed.

An interesting finding is that, considering the preliminary survey, different cities appeared in this second survey. It could suggest that this second survey reached new or different healthcare professionals from the preliminary survey. However, we do not have how to confirm this information over this second survey sample. Table 5.4 shows the city distributions on the survey respondents.

Table 5.4: Healthcare unity city of the respondents.

City	***N***	**%**
Porto Alegre/RS	10	32
Gravataí/RS	4	13
Canoas/RS	3	10
Torres/RS	3	10
Campo Bom/RS	2	7
Passo Fundo/RS	2	7
Santa Cruz do Sul/RS	2	7
Alvorada/RS	1	3
Cachoeirinha/RS	1	3
Camaquã/RS	1	3
Pelotas/RS	1	3
Sapucaia do Sul/RS	1	3

Soure: The authors

5.2.2 Experience on MTS and ESI Protocols

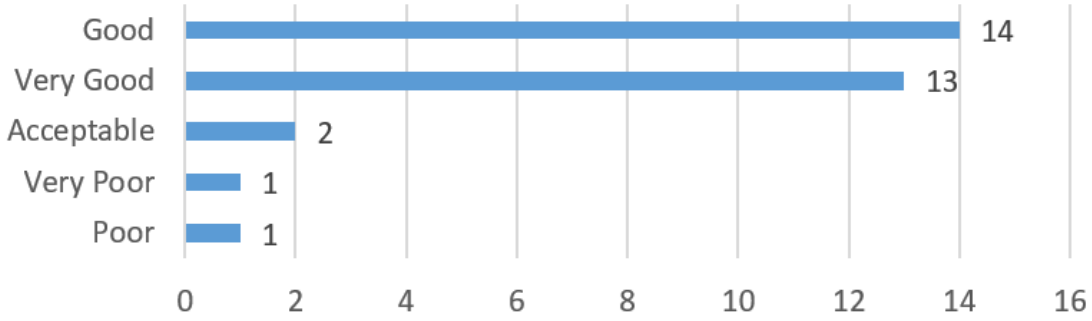
An interesting aspect to the phase of evaluating our process models with domain experts was to reach healthcare professionals with practical experience in the triage process and, if available, with some knowledge level on the specifics triage protocols.

Since we used the triage protocol implantation guidelines as business documentation to extract the process models, this aspect would allow us to confront the process model with the survey participant during the individual meeting, not only over a triage process itself but on a specif triage protocol context.

Our survey sample showed an interesting awareness of the MTS and ESI triage protocols. In the question about the respondents' knowledge level on the MTS protocol, our survey sample was around 87% with a *Good* or a *Very Good* knowledge level on the Manchester model.

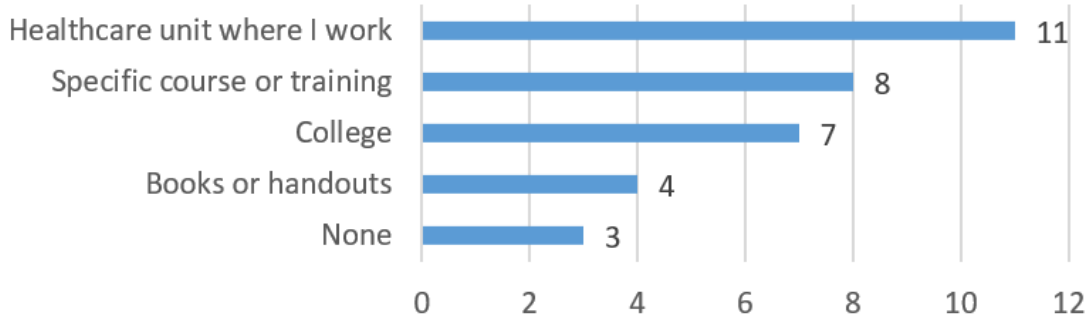
When asked where they considered achieved this kind of information, the *Health-care unit* where they work/worked appeared as the main source with 11 votes, followed by *specific courses*, with eight votes. Fig. 5.1 shows the distribution of the levels on the MTS protocol, and Fig. 5.2 shows where the respondents considered achieved this knowledge.

Figure 5.1: Respondents' knowledge level on the MTS protocol.



Source: The authors

Figure 5.2: Main respondents MTS knowledge level source.

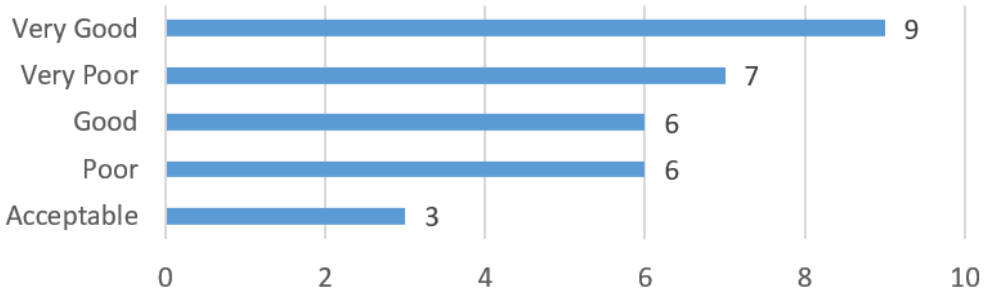


Source: The authors

This situation changed when asked about the respondents' knowledge level on the ESI protocol. Almost half of our survey sampling (48%) had a *Good* or a *Very Good* knowledge level on the American model. When asked where they considered achieved this kind of information, 13 respondents did not select any of the available options nither informed another source. The Healthcare unit where the respondent work/worked was the second source most selected, with seven votes.

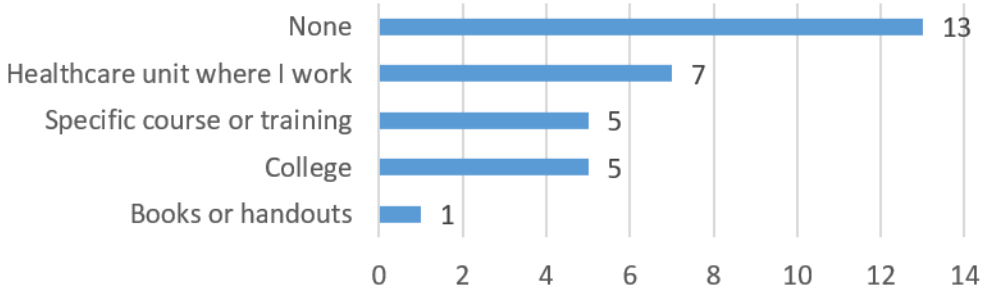
Fig. 5.3 shows the distribution of the levels on the ESI protocol, and Fig. 5.4 shows where the respondents considered achieved this knowledge.

Figure 5.3: Respondents' knowledge level on the ESI protocol.



Source: The authors

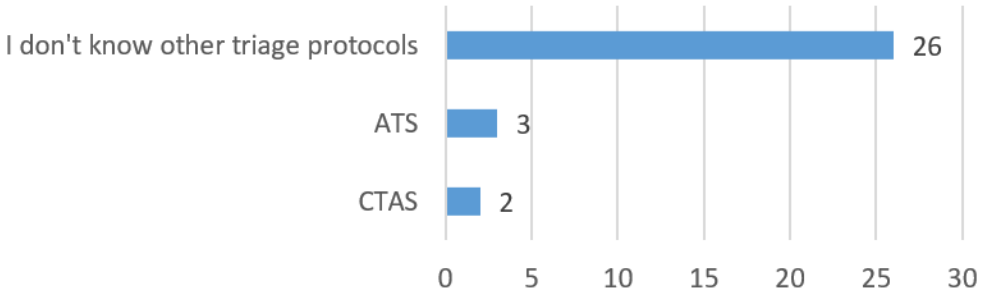
Figure 5.4: Main respondents MTS knowledge level source.



Source: The authors

Additionally, when asked if the survey respondent knew other triage protocols (i.e., the ATS, CTAS, or even another protocol), only five respondents select the protocols studied in this work, as shown Fig. 5.5. This question was intended to identify other protocols the survey respondent may also knew and, if possible, discuss them as a way to identify other triage protocols' particularities besides the MTS and ESI protocols.

Figure 5.5: Others triage protocols known by the survey respondent



Source: The authors

5.2.3 Survey Invitation

In the last questionnaire question, where we invited the respondent to participate in our next survey step, 19 survey respondents (from all 31 participants on this survey) agreed to participate in the next step by informing a way of contact (i.e., e-mail address or phone number).

Table 5.5 shows the profile (i.e., academics degree, experience time performing triage activities, and the knowledge level on the MTS and the ESI triage protocols) of the 19 respondents who agreed to participate in the following survey step. This set of healthcare professionals volunteers will serve as input to our individual interview selection.

Table 5.5: Respondents profile information

N	**Academics degree**	**Experience**	**MTS**	**ESI**
01	Nurse tech.licensed	$\geq$ 10 years	Good	Very Good
02	Nursing graduated	$\geq$ 10 years	Good	Good
03	Nursing graduated	$\geq$ 10 years	Good	Good
04	Nursing graduated	$\geq$ 10 years	Good	Acceptable
05	Nursing graduated	6-10 years	Good	Poor
06	Nursing graduated	3-5 years	Very Good	Very Good
07	Nursing graduated	3-5 years	Good	Very Good
08	Nursing student	3-5 years	Very Good	Poor
09	Nursing graduated	3-5 years	Good	Good
10	Nursing student	1-2 years	Very Good	Very Poor
11	Nurse tech.licensed	1-2 years	Acceptable	Good
12	Nurse tech.licensed	1-2 years	Good	Poor
13	Nursing graduated	1-2 years	Poor	Poor
14	Nurse tech.licensed	$\leq$ 1 year	Very Good	Very Good
15	Nursing graduated	$\leq$ 1 year	Very Good	Very Good
16	Nurse tech.licensed	$\leq$ 1 year	Very Good	Acceptable
17	Nurse tech.licensed	$\leq$ 1 year	Good	Acceptable
18	Nursing graduated	No experience	Very Good	Very Good
19	Nurse tech.licensed	No experience	Good	Very Poor

Soure: The authors

5.3 Individual Interview Selection

For the purposes of this work and the available research time, we have as objective to conduct individual interviews with three to five different healthcare professionals. Thus, it was essential to decide on an ordination-criteria to start the survey individual meeting invitation.

Considering the Table 5.5, the participant's number (i.e., column 'N') is related to the invitation order that we used according to two criteria we applied.

We applied two ordination criteria to our survey sampling before inviting the participants. Since our work was focused on healthcare professionals with practical experience, the first ordination selection was about the time experience performing triage activities, where we ordered the participants according to the experience time informed in this survey, in decreasing order.

The second-order criteria were about the knowledge level on the MTS or ESI triage protocol informed by the participant, from the Very-Good to the Poor level.

After the order-criteria application, we started inviting activities. This survey phase occurred during May 2020 and, due to the COVID-19 pandemics in Brazil, we decided to perform only web meetings, keeping the social distancing policies.

Initially, we invited by e-mail the first ten respondents asking, if possible, to schedule an individual meeting through the interviewed preference online platform (e.g., Skype, Google Meet, Zoom) and discuss the practical use of triage protocols in emergency departments.

In this group, only respondents 03, 01, 08, and 06 returned our invite (in this order) to schedule an individual interview. Then, we invited the following two participants (11 and 12), where only respondent 12 returned our invite. Table 5.6 shows the profile information of the five healthcare professionals interviewees.

Table 5.6: Respondents profile information

Respondent	**Academics degree**	**Experience**	**MTS**	**ESI**
A	Nursing graduated	$\geq$ 10 years	Good	Good
B	Nurse tech.licensed	$\geq$ 10 years	Good	Very Good
C	Nursing student	3-5 years	Very Good	Poor
D	Nursing graduated	3-5 years	Very Good	Very Good
E	Nurse tech.licensed	1-2 years	Good	Poor

Soure: The authors

5.4 Final Considerations

This chapter presented our second survey performed with healthcare professionals with experience time performing the triage process. At the end of the survey, we invited a set of participants to an online interview to evaluate our triage protocol process model.

Chapter 6 presents the interview with five healthcare professionals and the evaluations of our triage protocol process models and description proposals.

6 PROCESS MODEL EVALUATION

This chapter presents the individual meeting we performed with the healthcare professionals to evaluate our triage protocol process models and their descriptions. This set of interviews with domain experts allows us to evaluate the adherence of the process model to the actual triage process (achieving our G2) and also verify this works' second hypothesis (H2).

6.1 Individual Interviews

During the online interview with the healthcare professional, we shared and presented our triage process model, reading and describing the process model description.

Considering that not all participants were familiar with the BPMN terminologies or elements, we used no technical terms to describe the model process. When the participant point out a process modeling difference (e.g., an activity, a sequence flow), we asked them if it was according to what they learned about the triage protocol or what they practiced on the triage process.

At the end of the meeting, we conduct a free speech interview where the interviewee could highlight any aspect they judge relevant to the triage process, the triage protocol, or our triage models. This approach allows us to get insights into the triage process that may not appear in the process documentation available (DUMAS et al., 2018).

With these individual meetings with healthcare professionals, we could verify some triage aspects related to the triage protocol implantation guidelines used to model the triage process. We also had the opportunity to identify some BPMN constraints to express the triage process according to the interviewee feedbacks, as we report as follows.

6.2 BPMN for Triage Process

We report and discuss our findings related to the process evaluation and the BPM notation representing triage processes in the following subsections. Although the interviews were performed individually with the healthcare professionals, we decided to group the findings by common subjects to discuss them.

6.2.1 Different Priorities Levels and Use of Colors

There are activities and clinical situations in a triage context that are more critical than others, requiring more nurses' attention and awareness. The use of colors to visually indicate different triage levels seems to be a pattern since all five healthcare professionals reported the adoption of colors along the triage process in the emergency rooms where they work or worked.

The adoption of colors included the use on the patient's wrist band (i.e., a bracelet attached to a patient's wrist at the time of admission with the purpose of health caring information and personal identification), on the patient's medical record, and in some cases, to physically demarcate and identify different treatment areas in the emergency departments (e.g., the Resuscitation Room with red color identification, the Medication Room with green color identification).

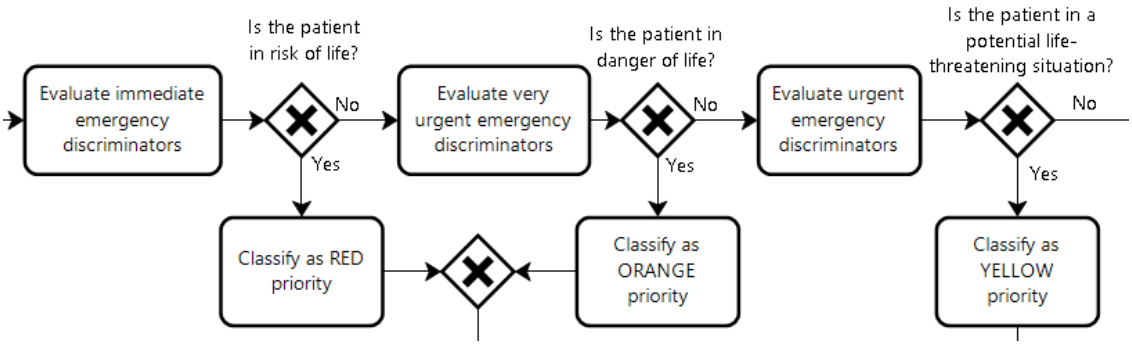
The set of colors used to differentiate the urgency level was not a consensus between the respondents, despite the emergency department's triage protocol adopted. For example, respondents A, B, and D related the adoption of colors (in order of the urgency priority) as *red*, *orange*, *yellow*, *green*, and *blue*. In contrast, respondents C and E related colors *red*, *orange*, *green*, *blue*, and *white* to differentiate the clinical criticality levels.

Since the BPMN does not normative the use of colors (OMG, 2013), we address this aspect by two different modeling approaches. In the first one, we set the triage tasks in a criticality order, where the most critical activity is executed first, then the second more critical activity is executed, and so forth. This strategy was used to model the activities with different clinical priorities in the MTS model since this protocol is more explicitly by indicating a list of discriminators according to the emergency level.

The Fig. 6.1 shows the MTS process model fragment with this approach applied. The activity "*Evaluate immediate emergency discriminators*" is the most critical activity evaluation because it can lead to a RED priority if the patient is in a risk of life situation, so this activity must be executed first. In a negative answer, the "*Evaluate very urgent emergency discriminators*" is executed, and then the activity of "*Evaluate urgent emergency discriminators*".

In the second approach, the activity of performing the patients' assessment happens before the assignment of a triage classification. The Fig. 6.2 shows the CTAS model process fragment with this second approach applied. The activity <*Perform the patient's assessment*> is executed right before the <*Assign an acuity level*> activity. Then, through

Figure 6.1: The MTS process model fragment



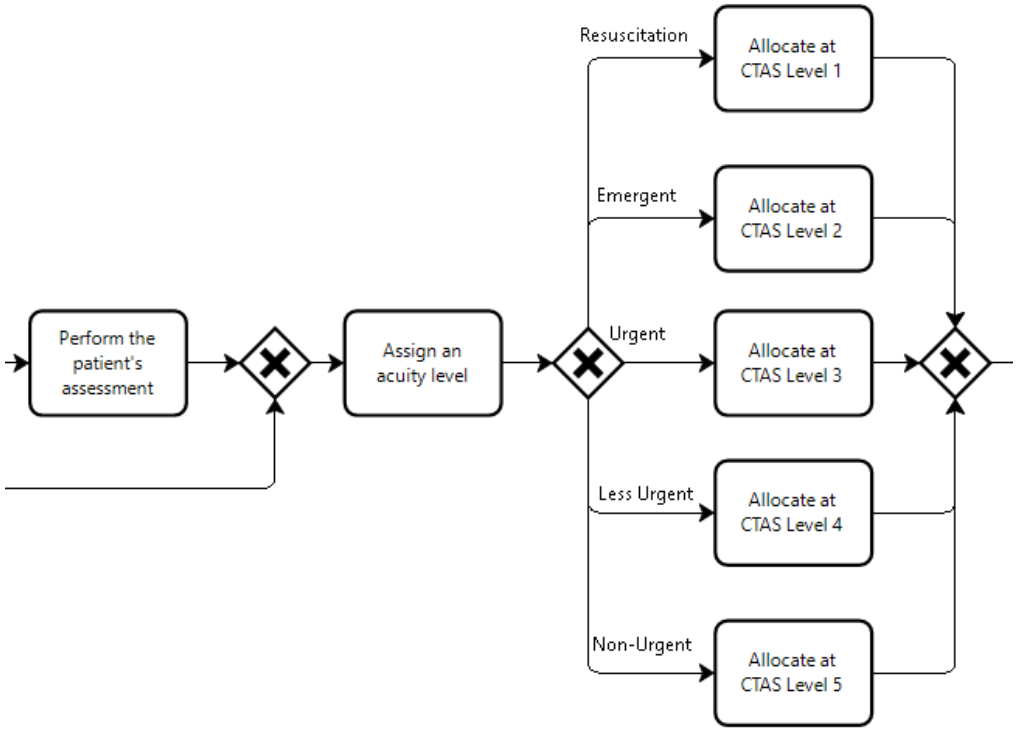
Source: The authors

an exclusive gateway element, the triage nurse chose the proper triage category according to the priority level, ordered from the top to the lane's bottom.

None of the five survey respondents pointed out that our process model was semantically wrong in this aspect, despite the approach adopted to model different clinical priorities.

When asked which model approach they preferred to represent the process model according to the reality, respondent A, B, and D informed a preference for the MTS approach. Respondents C and E do not manifest an approach preference since they considered the information represented in the process model was correct.

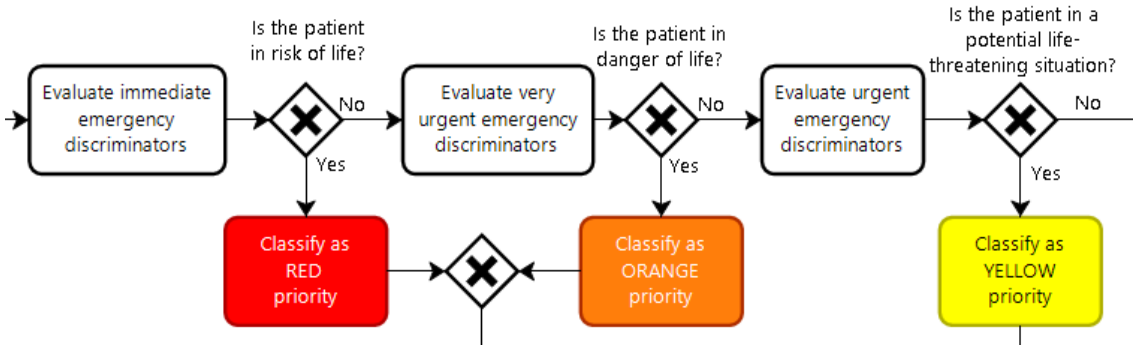
Figure 6.2: The CTAS process model fragment



Source: The authors

Since the adoption of colors to differentiate clinical priorities was an aspect reported by all five respondents as something to improve on the process model, there is the possibility of exploring other approaches to represent this information in a process model. Our first proposal is to explicitly adoption of colors in the activities to model the triage process with BPMN notation and address this issue. The Fig. 6.3 shows the MTS process model fragment with the explicit use of colors on the activities to visually differentiate the clinical urgency levels.

Figure 6.3: The MTS process model fragment - Activities Colors



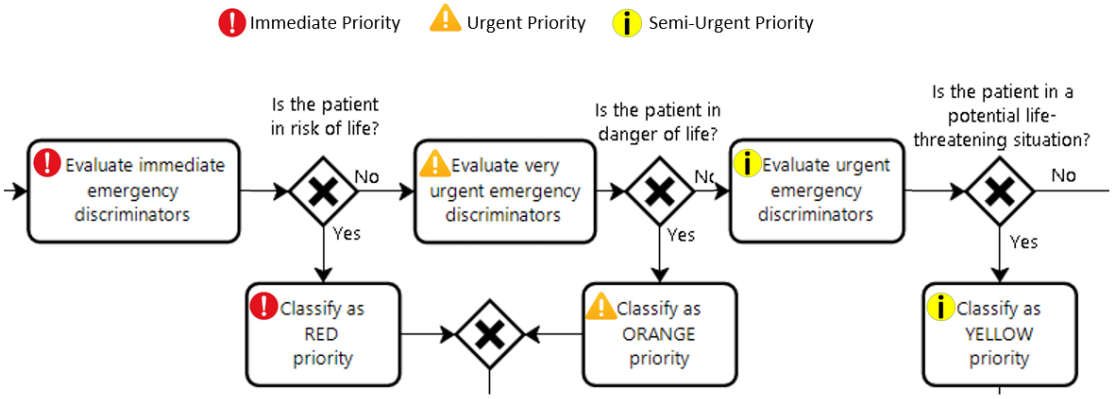
Source: The authors

Since the BPMN 2.0 introduces an extensibility mechanism that allows extending standard BPMN elements with additional attributes (OMG, 2013), another approach is to create an activity marker or a stereotype task to differentiate the activities with different clinical priorities. For example, Fig. 6.4 shows the MTS process fragment with specific color markers on the activities to visually differentiate the clinical urgency levels.

An advantage of this approach is the possibility of mark all the activities that are related to a specific critical activity, such as marked in the activity "*Evaluate immediate emergency discriminators*" and then in the "*Classify as RED priority*", illustrating that the *all path* has an immediate priority.

Another possible approach is to adapt the modeling convention to address this issue (e.g., where the top element in a lane has the highest priority and must be performed first), as adopted in Fig. 6.2.

Figure 6.4: The MTS process model fragment - Activities Markers



Source: The authors

6.2.2 Five Levels of Scales

Triage protocols that use classification with five-priority levels are better in validity and reliability compared to models that use only three-rating levels (CHRIST et al., 2010; GILBOY et al., 2011). In our survey, all five healthcare professionals interviews reported the use of triage protocol only with five levels of scale in the emergency departments they work. When asked if they have studied or worked with any other triage protocols with different levels of scale, all participants indicated a negative answer.

During the interview, participant D described a project where he was a member of to build the triage process to a new emergency room at a hospital where he worked before. In this project, the clinical staff in charge performed a triage protocol selection to use as a model for the new triage process.

A significant requirement of creating the triage process for this emergency room was to use a triage process with five classification levels since "*it was consensus between the clinical staff about triage protocols with five classification levels being an international pattern*". As a result of the triage protocol selection, the MTS (MACKWAY-JONES; MARSDEN; WINDLE, 2014) protocol was chosen as input to build a custom new triage process in the participant D project.

Considering the healthcare professionals' feedbacks and the surveys performed in this work, it seems to be a pattern confirming the preference for utilizing triage classification with five levels of scale, as indicated in the literature. Thus, in this aspect and according to all five healthcare professionals, our triage protocols process model was adherence to the triage process reality.

However, we highlight that there is nothing specific in our process modeling approach or in our triage protocol process model that inhibits the process modeling of a triage protocol with more or fewer urgency levels, as long as all the modeling guidelines and quality aspects presented in this work continue to be followed.

6.2.3 Time Restriction

Observing and pursuing the time restrictions of starting or finishing a patient's clinical evaluation is essential, and respecting this goal is literally life-saving in the triage reality. However, it seems not to be a consensus about the set of "urgency level vs. time limit" along the triage process.

Some respondents reported that, although the existence of a time limit to assess and attend to the incoming patient, sometimes it is necessary to prioritize patients with a higher urgency level over the lowest ones (e.g., when the emergency department is overcrowded).

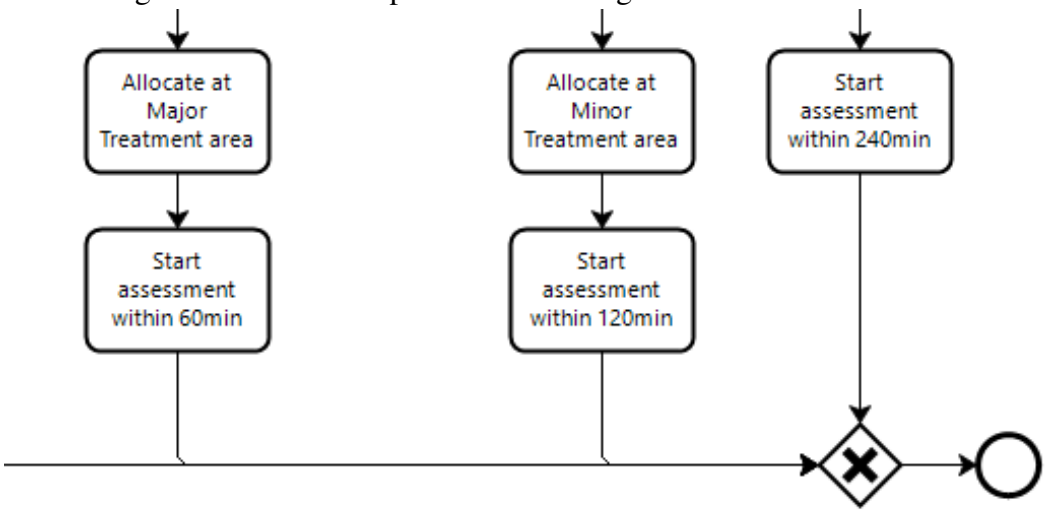
This situation may lead to a waiting time superior over the time stipulated at the less urgent levels. According to respondents A and B, adopting the re-triage process to monitoring the patients could mitigate this situation.

Although BPMN has *timer events* that explicitly start a task or change a sequence flow, we addressed this aspect in our process models by adding the time restriction information in the task label as a way to ensure the flexibility that a healthcare domain requires (COMBI et al., 2016). Fig. 6.5 shows the MTS process model fragment with this time descrition, as shonw in the activities "*Start assessment within 60min*", "*Start assessment within 120min*" and "*Start assessment within 240min*".

All the five survey respondents reported the need to have this information in a straightforward and highlighted way, even the respondents with good knowledge level (i.e., respondents A, B, and D) about the ESI triage protocol, which does not specify time restrictions. Although this observation, the information represented in our triage protocols process model was correct about the real process.

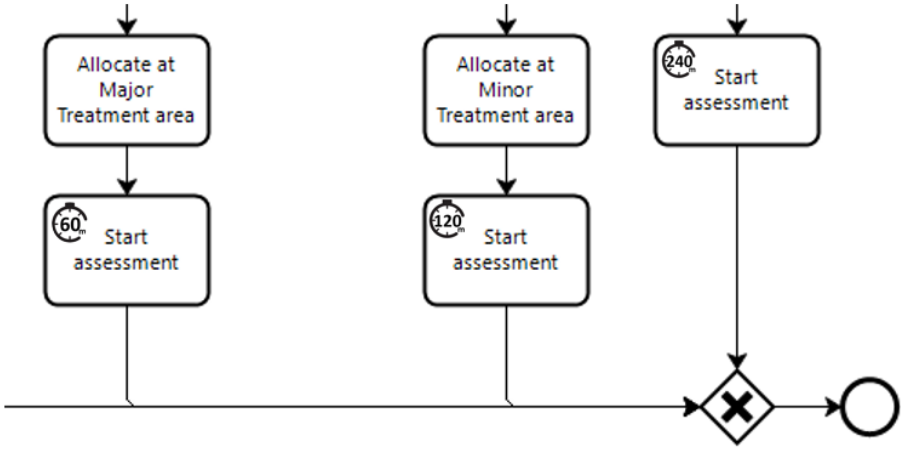
A proposal to address this issue is to create an activity marker to explicitly indicate the time restrictions in the process model. For example, Fig. 6.6 shows the same MTS process fragment with specific clock markers on the activities to visually highlight the time restriction according to the assessment activity.

Figure 6.5: The MTS process model fragment - Time Restrictions



Source: The authors

Figure 6.6: The MTS process model fragment - Time Markers



Source: The authors

6.2.4 Triage Roles

The four triage protocols previously considered in this study indicate the *triage practitioner* (i.e., a trained nurse) and the *physician* as the triage process's roles. However, two survey respondents reported the *administrative agent* as a significant role involved in the triage process. Although this role does not perform some activity in the triage process per se, the administrative agent is usually the patient's first contact in emergency departments.

The administrative agent's principal activities are to provide general orientation about the attendance process, register the incoming patient in the emergency department system, check the patients' documents information, and (if necessary) the patients' health

insurance plan.

Thus, the administrative agent must have triage skills to perceive critical situations where the patients must be seen immediately by the nurse or physician. Not rare, the administrative agent activities occur alongside the triage practitioner activities.

Although this specific role does not change our triage protocols process model directly, we believe that having the opportunity to interview this role could give us another perspective about the triage process, providing new insights and outcomes that could lead to process model enhancements.

6.2.5 Clinical Exams and Vital Signs

Although the nurse does not request it during the triage performing, clinical exams already done by the patient can help triage decisions along the process. Similarly, the vital signs information is an essential triage process input. This information accompanies the patient during all the assessments, helping triage decision takings, and sometimes (according to the patients' clinical situation), it is continuously monitored and checked.

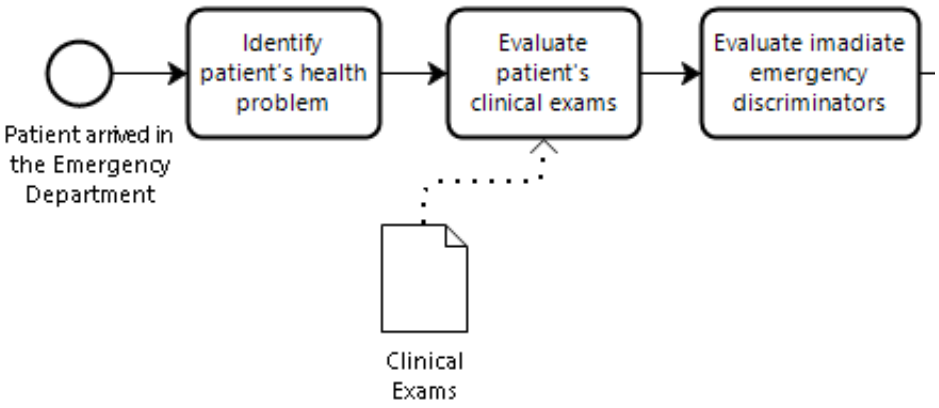
The use of this set of data information (clinical exams and vital signs measurements) emerged during the process evaluation with de triage practitioners, and it was not covered in our process models. In the triage protocols guidelines used to model the triage process, only the ESI triage protocol considers the use of clinical exams in its flow, but at the moment where the triage nurse needs to evaluate the number of required resources for the patient care.

Although we did not have the opportunity to perform a second round of process model evaluations with the triage practitioners in our survey, we believe using the BPMN Data Object (or specific stereotypes) in the process models could improve the expressiveness of the model. Fig. 6.7 shows the MTS process fragment with a Data Object representing the patients' clinical exams and the activity "*Evaluate patient's clinical exams*" at the beginning of the triage process.

6.2.6 Reassessment

Although the MTS or ESI triage protocol does not specify guidelines to perform the re-triage process, according to all respondents in our survey, each emergency department

Figure 6.7: The MTS process model fragment - Clinical Exams



Source: The authors

can specify internal policies to formalize or not this process.

For example, in the emergency department where respondent C works, there is no formal process to reassess patients. However, the triage performer must always be alert to any deterioration signal of the patient's clinical condition in the waiting area (e.g., a patient with an initial non-urgent classification). In this situation, a new re-triage process must be performed considering the new incomes about the patient's condition.

6.2.7 Process Model Quality

By the end of the online interview, we asked the respondents two specifics questions. The first one was related to the process model and the real process: "*According to your triage experience, do you consider that these triage protocol process models represent the triage process in reality?*". The healthcare professionals considered that our process model represents the triage process as it occurs in the real world.

We consider this an essential finding for this work purposes for two reasons. First, this finding endorses our process model semantic quality aspect by validating the process models' adherence to the real triage process. Thus, we consider that our second goal presented in Chapter 1 (i.e., Evaluate the adherence of the triage protocols process model to the actual triage process) was achieved with this finding.

Second, this finding also confirms that the triage process represented in the triage protocol implantation guidelines is trustful compared to what is practiced in emergency departments in south Brazil.

The second question was about the process model usability: "*Would you consider*

using these process models during your triage activities performing? How?". All five healthcare professionals considered using the process models but with different purposes. For example, respondents A, C, and E considered using the triage protocol process models as a triage guide during the activities.

Respondent B specify the opportunity to use the process model on the wall of different emergency rooms or waiting areas to inform and illustrate to the incoming patients about the triage process used in that emergency room.

Respondent D also stated that "*improving the use of colors and the time restrictions issues (explicitly displaying this information on the process models), there is the opportunity to use these models to adapt the triage process as new emergency needs arise, as happens with emergency rooms during the 2020 COVID-19 pandemics*".

We consider these second question feedbacks as a solid evidence to confirm our process model pragmatic quality, since the healthcare professionals confirmed the practical use of the triage protocols process models evaluated.

6.3 Final Considerations

This chapter presented the online interviews with healthcare professionals to evaluate our proposal of the triage protocol process model and its process description.

Significant findings emerged from this process model evaluation with the healthcare professional. We highlight as important findings the confirmation of the process models adherence to the real triage process and its opportunity of practical use as triage guides or to illustrating to the incoming patients about the triage process performed in the emergency department.

We also highlight two important BPMN aspects about representing the triage process, such as the need to explicitly displaying the information about the colors (to distinguish the emergency levels visually) and time restrictions inherent to triage activities. We consider that all these findings support us with enough evidence to confirm our second hypothesis about improving the representation and standardization of triage protocols through a BPM approach.

Chapter 7 presents our final conclusions, limitations and future works about this research.

7 CONCLUSIONS

In this work, we performed a set of surveys with healthcare professionals in south Brazil, where we collected important information about the practical use of triage protocols in the emergency room reality. In the first survey, with 34 respondents, significant findings emerged, confirming the adoption of triage protocols in emergency departments and their relevance to healthcare professionals.

Almost all of our survey sampling uses some protocol to perform triage activities (94%), and to all of them, triage protocols are Important (38%) or Very Important (62%) to perform their activities. This information was very important to this work since we could confirm our first hypothesis about the adoption and importance of triage protocols to healthcare professionals, at least in the context of this survey application.

Another finding that emerged in this survey is about using customized protocols as the second triage protocol mainly used, and that the current protocols used by healthcare professionals do not have all the relevant information to perform the triage activities. We consider these findings substantial evidence of the non-standard on the triage protocols and the opportunity to improve the information representation in the triage protocols.

The use of BPM to manage critical processes and mapping clinical decisions is not relatively new (ZERBATO et al., 2015), going from complex disease treatment mappings (SCHEUERLEIN et al., 2012; KOPECKY; TOMASKOVA, 2020) to the hospital diagnosis and therapy process (BRAUN et al., 2014; MÜLLER; ROGGE-SOLTI, 2011). To explore the triage protocols' aspects through a process-oriented approach, we performed a BPM process discovery, extracting the process elements from the four official triage protocols' business documentation and generated its process models following a set of process modeling quality guidelines.

In a second survey, we conducted a set of interviews with five healthcare professionals to evaluate these process models and how BPMN can represent triage protocols. Our findings indicate a good acceptance of the process models in BPMN in the opinions of the healthcare professionals interviewed, mainly by the adherence to the real triage process and its opportunity of practical use as triage guides or to illustrating to the incoming patients about the triage process performed in the emergency department. All these findings give us enough information to confirm our second hypothesis about improving the representation and standardization of triage protocols through a BPM approach.

During the interviews, we could also identify some BPMN constraints representing

triage processes, such as using colors to express different clinical priorities and representing the time restrictions according to the emergency triage activity. Although we did not have the opportunity to perform a second round of process model validations with the triage practitioners in this work, we believe that extending some BPMN elements with additional attributes could effectively address these issues.

7.1 Threats to Survey Validity

The main threat to the validity of our study is related to the survey respondents. We reached 34 healthcare professionals with different academic degrees and triage process knowledge in the first survey and 31 healthcare professionals in the second one.

About these bove survey applications, we can not have how to validate if a first survey respondent has or has not participated in the second survey. Thus, we can not affirm if the second survey findings are from a new sampling or are from the same (or even similar) first survey sampling.

Another threat is related to the respondent's knowledge in the second survey. As we did not have how to validate or prove the respondent's knowledge informed or where they achieved this kind of information, we assumed the respondents' self-evaluation was valid for the purposes of this research.

We believe our survey sample profiles support us with enough information to gather insights and achieve significant conclusions about the use of triage protocol in emergency departments. However, to arrive at general conclusions through empirical studies is difficult since any process depends on a considerably large number of relevant context variables (BASILI; SHULL; LANUBILE, 1999).

Since our research was conducted with professionals predominantly from Porto Alegre/Brazil and region, we can not assume that the results will generalize to all healthcare professionals, hospitals, or even regions. Nevertheless, our study does nothing specific or different that prevents replication in other contexts or conditions.

Replicating our research in other emergency departments' contexts will help generalize its results and build an empirical knowledge set.

7.2 Future Works

Some opportunities for future works emerged from our research. The first possibility is to evaluate the process models' practical use in a real emergency department context. Considering these work findings, where the MTS protocol was the triage protocol most used by the respondents in our preliminary study presented in Chapter 3, reinforced by the respondents' MTS knowledge level presented in Chapter 5,we believe that the MTS Process Model presented in Fig. 4.4 is a candidate for this real scenario evaluation. This triage protocol also predicts attendance to diverse clinical complexities levels, enabling evaluations in different emergency department contexts.

This work also enables a formal extension of BPMN for the triage process perspective, focused on the triage protocol elements modeling. To guarantee the pragmatic quality aspect of the BPMN extension is imperative a new process model validation by the users involved in the triage process (e.g., triage nurse, physician, administrative agent). This approach could expand our work and the triage research field.

A formal BPMN extension representing all the triage process elements and its information allows the adaption or creation of different triage protocols as new emergency department realities emerge, as happens with emergency rooms during the 2020 COVID-19 pandemics.

New surveys about the triage process with different healthcare professionals or emergency department contexts (i.e., other Brazil regions or countries) could reinforce our findings or produce new ones, bringing ampleness and new insight to this work.

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APPENDIX A — FIRST QUESTIONNAIRE

Questionário sobre o uso de protocolos de Classifcação de Risco e de Triagem em unidades de urgência e emergência.

Sessão 1 - Sobre essa pesquisa: O objetivo desse questionário é coletar informações sobre o uso de protocolos de Classificação de Risco (atividade também conhecida como Triagem) em unidades de urgência e emergência, como Hospitais, Pronto Socorros e Unidades de Pronto Atendimento (UPAs) e é direcionado aos profissionais da saúde que possuem algum conhecimento ou experiência prévia nesses procedimentos. Se você concordar em participar desta pesquisa, pedimos que você leia cada seção com atenção para poder responder às perguntas apresentadas. Esse questionário contribui para a pesquisa de Mestrado de Michel Cristiano Gonçalves (*michel.goncalves@inf.ufrgs.br*), orientado pela Profa. Dra Lucineia Heloisa Thom (*lucineia@inf.ufrgs.br*), do Instituto de Informática da Universidade Federal do Rio Grande do Sul. Nenhuma informação de identificação pessoal será solicitada ou coletada durante o preenchimento desse questionário.

1 - Qual a sua formação na área da saúde? (resposta única)

- Graduação em Medicina - formado;
- Graduação em Medicina - em andamento;
- Graduação em Enfermagem - formado;
- Graduação em Enfermagem - em andamento;
- Técnico em Enfermagem - formado;
- Técnico em Enfermagem - em andamento;
- Não possuo formação na área da saúde;
- Outro;

2 - Qual o seu tempo de experiência realizando procedimentos de Classificação de Risco ou Triagem? (resposta única)

- Não possuo experiência;
- Menos de 1 ano;
- De 1 a 2 anos;
- De 3 a 5 anos;
- De 6 a 10 anos;
- Mais de 10 anos;

3 - Qual a principal unidade de saúde que você atuou realizando procedimentos de Classificação de Risco ou Triagem? (resposta única)

- Hospital;
- Unidade de Pronto Atendimento (UPA);
- Unidade Básica de Saúde (UBS);
- Outro;

4 - Qual a cidade da principal unidade de saúde que você atuou realizando procedimentos de Classificação de Risco ou Triagem? (resposta única)

- Alvorada/RS;
- Canoas/RS;
- Porto Alegre/RS;
- Viamão/RS;
- Outro;

Sessão 2 - Identificação dos Protocolos Triagem: A principal finalidade das atividades de Classificação de Risco é a definição da ordem do atendimento em função da gravidade clínica apresentada pelo paciente. Os protocolos de Classificação de Risco são instrumentos que sistematizam a avaliação do paciente. E o uso de protocolos existentes na literatura é uma oportunidade de valorização dos trabalhadores da urgência.

5 - Você utiliza algum protocolo ou procedimento estruturado (com passos claros a serem seguidos) nas suas atividades de Classificação de Risco ou Triagem dos pacientes? (resposta única)

- Sim, utilizo um protocolo definido e bem estruturado;
- Sim, utilizo um protocolo, mas não estruturado ou não bem definido;
- Não utilizo um protocolo definido nas minhas atividades de Classificação de Risco;

6 - A seguir estão listados alguns dos principais protocolos de Classificação de Risco e de Triagem utilizados para classificação de emergência de pacientes. Marque abaixo o(s) protocolo(s) que você conhece: (múltipla escolha)

- Protocolo Manchester de Triagem (MTS - *Manchester Triage System*);
- Protocolos Australiano de Triagem (ATS - *Australasian Triage Scale*);
- Protocolo Canadense de Triagem (CTAS - *Canadian Triage Acuity Scale*);
- Protocolo Americano de Triagem (ESI - *Emergency Severety Index*);

- Desconheço os protocolos listados acima;
- Outro;

7 - Considerando ainda os principais protocolos de Classificação de Risco e de Triagem utilizados para classificação de emergência de pacientes, marque abaixo o(s) protocolo(s) que você utiliza nas suas atividades: (múltipla escolha)

- Protocolo Manchester de Triagem (MTS - *Manchester Triage System*);
- Protocolos Australiano de Triagem (ATS - *Australasian Triage Scale*);
- Protocolo Canadense de Triagem (CTAS - *Canadian Triage Acuity Scale*);
- Protocolo Americano de Triagem (ESI - *Emergency Severety Index*);
- Utilizo um protocolo específico elaborado pela unidade de saúde onde atuo;
- Não utilizo os protocolos listados acima;
- Outro;

Sessão 3 - Uso Prático dos Protocolos: Existem algumas orientações para uma implementação de um protocolo de Classificação de Risco nos serviços de urgência e emergência: O protocolo deve explicitar com clareza qual o encaminhamento a ser dado uma vez que o risco é classificado; Recomenda-se que o protocolo tenha no mínimo quatro níveis de classificação de risco; Recomenda-se o uso preferencial de cores, e não de números, para a classificação de risco; A classificação de risco é dinâmica, sendo necessário que o risco atribuído aos pacientes seja periodicamente reavaliado.

8 - Caso você utilize algum protocolo específico de Triagem, marque abaixo as características que esse protocolo possui: (múltipla escolha)

- Definição de TEMPO MÁXIMO para atendimento;
- Classificação de risco em QUATRO níveis;
- Classificação de risco em CINCO níveis;
- Uso de NÚMEROS (e não cores) para os níveis de risco;
- Uso de CORES (e não números) para os níveis de risco;
- Definição sobre o ENCAMINHAMENTO (setor ou área) a ser dado ao paciente;
- Orientações ou procedimentos definidos para REAVALIAÇÃO dos pacientes.
- Não utilizo um protocolo de Classificação de Risco definido;
- Outro;

9 - Caso você utilize algum protocolo específico de Classificação de Risco ou de

Triagem, ele possui todas as informações que você acha relevante para a correta classificação de risco dos pacientes? (resposta única)

- Sim, totalmente;
- Sim, parcialmente;
- Raramente em algumas situações;
- Não, em nenhum momento;
- Não utilizo um protocolo de Classificação de Risco definido;

10 - Caso você utilize algum protocolo específico de Classificação de Risco ou de Triagem, esse protocolo é claro e de fácil utilização? (resposta única)

- Sim, totalmente;
- Sim, parcialmente;
- Raramente em algumas situações;
- Não, em nenhum momento;
- Não utilizo um protocolo de Classificação de Risco definido;

11 - Qual o grau de importância que você atribui ao uso de um protocolo de Classificação de Risco ou de Triagem na execução das suas atividades de classificação dos pacientes? (resposta única)

- Muito importante;
- Importante;
- Razoavelmente importante;
- Pouco importante;
- Sem importância;
- Não se aplica;

12 - Na sua opinião, em quais situações o protocolo de Classificação de Risco mais ajuda nas suas atividades de Triagem? (resposta livre)

APPENDIX B — SECOND QUESTIONNAIRE

Questionário sobre o uso de protocolos de Classifcação de Risco e de Triagem em unidades de urgência e emergência.

Sessão 1 - Sobre essa pesquisa: Essa pesquisa tem por objetivo coletar informações sobre o uso de protocolos de triagem em unidades de urgência e emergência, como Hospitais, Pronto Socorros e Unidades de Pronto Atendimento (UPAs). Essa pesquisa é direcionada aos profissionais da área da saúde que possuem algum conhecimento ou experiência prévia em procedimentos de triagem. Esse questionário contribui para a pesquisa de Mestrado em Ciências da Computação de Michel Cristiano Gonçalves (*michel.goncalves@inf.ufrgs.br*), orientado pela Profa. Dra. Lucineia Heloisa Thom (*lucineia@inf.ufrgs.br*), do Instituto de Informática da Universidade Federal do Rio Grande do Sul (UFRGS). Pedimos que você leia cada seção com atenção para poder responder às perguntas apresentadas. Essa pesquisa tem fins exclusivamente acadêmicos e nenhuma informação de identificação pessoal será solicitada ou coletada para o preenchimento desse questionário. Ao responder esse questionário, você estará concordando em participar da nossa pesquisa.

1 - Qual a sua formação na área da saúde? (resposta única)

- Graduação em Medicina - formado;
- Graduação em Medicina - em andamento;
- Graduação em Enfermagem - formado;
- Graduação em Enfermagem - em andamento;
- Técnico em Enfermagem - formado;
- Técnico em Enfermagem - em andamento;
- Não possuo formação na área da saúde;
- Outro;

2 - Qual o seu tempo de experiência realizando procedimentos de Triagem?

- Não possuo experiência;
- Menos de 1 ano;
- De 1 a 2 anos;
- De 3 a 5 anos;
- De 6 a 10 anos;
- Mais de 10 anos;

3 - Qual a principal unidade de saúde que você atuou realizando procedimentos de Classificação de Risco ou Triagem? (resposta única)

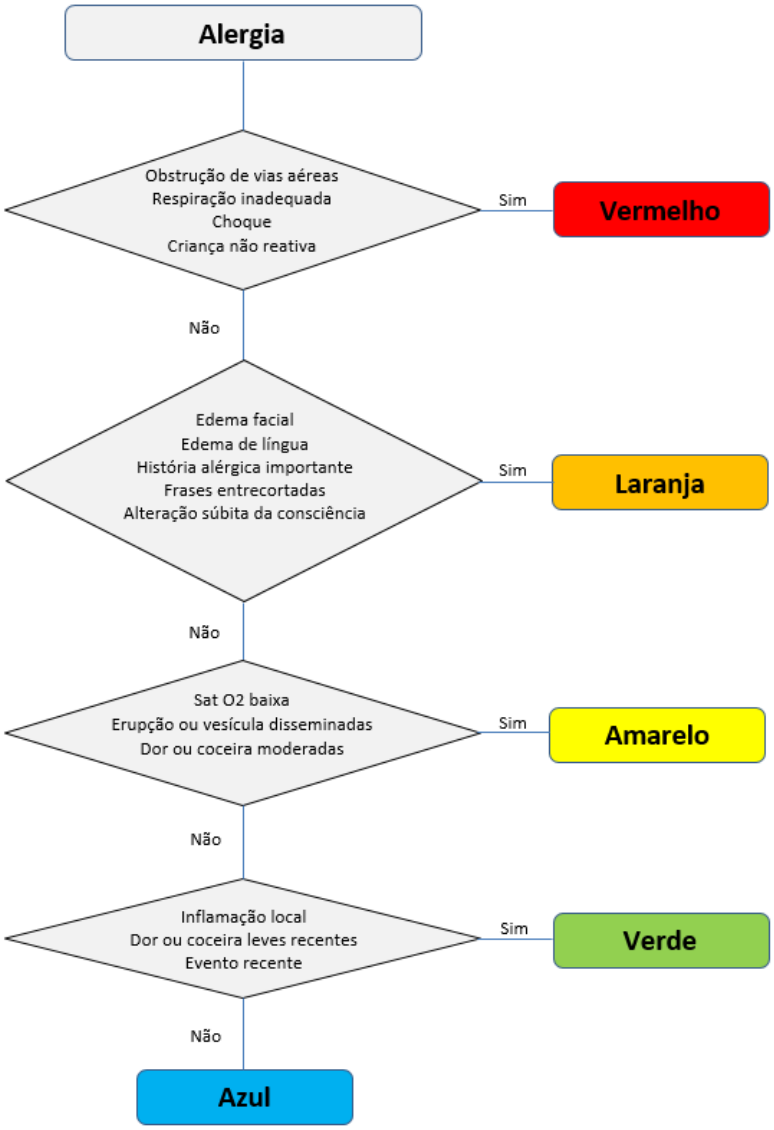
- Hospital;
- Unidade de Pronto Atendimento (UPA);
- Unidade Básica de Saúde (UBS);
- Outro;

4 - Qual a cidade da principal unidade de saúde que você atuou realizando procedimentos de Classificação de Risco ou Triagem? (resposta única)

- Alvorada/RS;
- Canoas/RS;
- Porto Alegre/RS;
- Viamão/RS;
- Outro;

Sessão 2 - Protocolo Manchester de Triagem: O protocolo Manchester de triagem (também conhecido como *Manchester Triage System* - MTS) teve sua primeira utilização em 1997, na cidade de Manchester na Inglaterra. Hoje ele é adotado como o protocolo padrão de triagem em sistemas de emergência de vários países da Europa, como Suécia, Espanha e Holanda. O protocolo Manchester define uma escala prioritária de CORES conforme o nível de urgência, considerando como entrada a queixa relatada pelo paciente. A imagem abaixo ilustra o enquadramento nos níveis de emergência conforme os sintomas apresentados pelo paciente com a queixa de “Alergia”.

Figure B.1: Protocolo Manchester - Alergia.



Fonte: Adaptado de Mackway-Jones, Marsden and Windle (2014)

5 - Como você avaliaria o seu nível de conhecimento (prático ou teórico) sobre o protocolo Manchester de triagem? (resposta única)

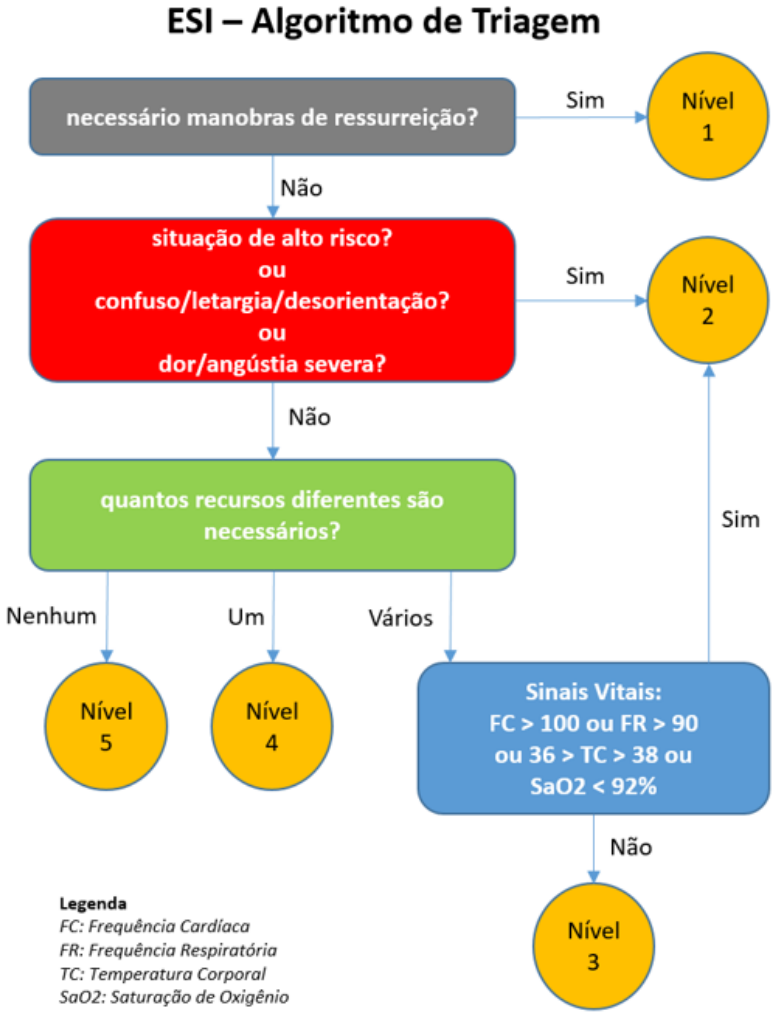
- Muito bom;
- Bom;
- Razoável;
- Pouco;
- Inexistente;

6 - Onde você consideraria que obteve esse conhecimento sobre o protocolo Manchester de triagem (múltipla esolha)

- Faculdade que eu curso/cursei;
- Cursos ou treinamentos específicos;
- Livros ou apostilas;
- Unidade de saúde onde trabalho/trabalhei;
- Nenhuma das opções acima;
- Outro;

Sessão 3 - Protocolo Americano de Triagem: A primeira versão do protocolo Americano de triagem (também conhecido como *Emergency Severety Index* - ESI) foi elaborada em 1999, e desde então vem sendo utilizado nos departamentos de emergência dos Estados Unidos da América. O protocolo Americano contempla um algoritmo específico com cinco níveis de gravidade, onde o Nível 1 é o mais grave e o Nível 5 o menos grave. Diferentemente dos outros modelos, esse protocolo considera também a QUANTIDADE DE RECURSOS necessários no atendimento do paciente (exames laboratoriais, raio-x, etc.).

Figure B.2: Protocolo Americano.



Fonte: Adaptado de Gilboy et al. (2011)

7 - Como você avaliaria o seu nível de conhecimento (prático ou teórico) sobre o protocolo Americano de triagem? (resposta única)

- Muito bom;
- Bom;
- Razoável;
- Pouco;
- Inexistente;

8 - Onde você consideraria que obteve esse conhecimento sobre o protocolo Americano de triagem (múltipla esolha)

- Faculdade que eu curso/cursei;
- Cursos ou treinamentos específicos;
- Livros ou apostilas;
- Unidade de saúde onde trabalho/trabalhei;
- Nenhuma das opções acima;
- Outro;

9 - Além dos protocolos Manchester e Americano listados anteriormente, quais outros protocolos de triagem você conhece ou possui experiência? (múltipla esolha)

- Protocolos Australiano de Triagem (ATS - *Australasian Triage Scale*);
- Protocolo Canadense de Triagem (CTAS - *Canadian Triage Acuity Scale*);
- Desconheço outros protocolos de triagem;
- Outro;

Sessão 4 – Agradecemos muito a sua participação na nossa pesquisa! Caso você possua algum conhecimento prático/teórico em algum dos protocolos de triagem listados nesse questionário, gostaríamos de convidar você ainda a participar da segunda etapa da nossa pesquisa, onde entraremos em contato (por e-mail ou telefone) para levantar maiores detalhes sobre o uso prático desses protocolos. Ressaltamos que essa participação não é obrigatória, mas contribuirá consideravelmente para a nossa pesquisa acadêmica.

10 - Você gostaria de participar da segunda etapa da nossa pesquisa sobre o uso prático dos protocolos de triagem? (resposta única)

- Sim, eu gostaria de contribuir para a próxima etapa da pesquisa;
- Não, obrigado. Desejo encerrar minha participação aqui.

11a - Por gentileza, informe um meio de contato (e-mail, Skype, telefone com DDD ou WhatsApp) para que possamos entrar em contato com você. (resposta livre)

11b - Agradecemos muito a sua participação na nossa pesquisa. (sem resposta)

APPENDIX C — RESUMO EXPANDIDO

Análise e Modelagem de Processos de Protocolos de Triagem - Um Estudo em Departamentos de Emergência no Sul do Brasil.

Departamentos de emergência recebem diariamente uma ampla variedade de pacientes com vários tipos de problemas, como ferimentos ou doenças. O processo de triagem é um mecanismo essencial para garantir que esses pacientes sejam tratados em sua urgência clínica, e não na ordem de chegada. De acordo com a literatura, existem diferentes protocolos de triagem adotados mundialmente, com quatro específicos se destacando como guia do processo de triagem em diversos países: o protocolo Australiano (*Australasian Triage Scale*), o protocolo Canadense (*Canadian Triage Acuity Scale*), o protocolo de Manchester (*Manchester Triage System*) e o protocolo Americano (*Emergency Severity Index*).

Nesse cenário, tem havido uma tendência de se estabelecer padrões e adotar um processo de triagem validado cientificamente para apoiar o atendimento clínico, o monitoramento e as atividades de pesquisa em pronto-socorros, trazendo benefícios diretos à qualidade da assistência ao paciente. Considerando o cenário Brasileiro, o process de triagem (também conhecido como Classificação de Risco), houve um esforço do Ministério da Saúde em 2004 para prover alguma orientação aos serviços de emergência quanto a padronização dos processos. Embora não tenha havido uma regulação formal ou explicita em como implantar um processo de triage no contexto de um departamento de emergência, há a recomendação para a adoção de um processo de triagem claro e bem definido.

Para investigar o contexto dos protocolos de triagem no sul do Brasil, realizamos uma abordagem orientada a processo através de uma Descoberta de Processos por meio *Business Process Management* (BPM). Nós extraímos os elementos de processo da documentação de negócio oficial dos protocolos de triagem e geramos seus modelos de processo, seguindo um conjunto de práticas de qualidade para modelagem de processos, como qualidade sintática, semântica e pragmática.

Por meio de um conjunto de pesquisas com profissionais de saúde com algum nível de experiência prática na realização de atividades de triagem em pronto-socorros do sul do Brasil, avaliamos como a BPM e sua notação (BPMN) podem melhorar a representação e padronização dos protocolos de triagem.

Nossos resultados confirmam a adoção de protocolos de triagem nos departamentos de emergência no sul do Brasil, principalmente pela adoção do protocolos Manchester e

também de modelos adaptados. Apesar do amplo uso, nossas pesquisas também indicaram que os protocolos utilizados não possuem toda informação relevante para o exercício das atividades de triagem pelos profissionais da saúde.

Sobre a validação dos nosso modelos de processos, consideramos que houve uma considerável aceitação dos modelos de processo em BPMN na opinião dos profissionais de saúde entrevistados, principalmente pela confirmação da aderência dos modelos apresentados ao processo de triagem real praticado. Outro ponto destacado foi a oportunidade de uso prático desses modelosde processos como guias de triagem, ou ainda, para ilustrar aos pacientes sobre o processo de triagem realizado no pronto-socorro que eles buscaram e em qual fase de atendimento eles se encontram.

Adicionalmente, reportamos um conjunto de aspectos sobre BPMN representando processos de triagem que surgiram durante as validações dos modelos de process com profissionais da saúde.

Como principais contribuições desse trabalho, nós destacamos:

Resutados das pesquisas quantitativas: Nós apresentamos e disponibilizamos nesse trabalho os resultados de duas pesquisas quantitativas realizadas com profissionais da saúde de diferentes unidades médica-hospitalares (e.g., Hospitais, Unidades de Pronto Atendimento e Unidades Básicas de Saúde) localizadas no rgião sul do Brasil. Nós performamos essas pesquisas como uma forma de atingir um entendimento mais aprofundado sobre a adoção e uso prático de protocolos de triage no context de unidades de emergência.

Modelos de Processo dos Protocolos de Triagem: Para avaliar e analçisar os protocolos de triage descritos na literature, nós modelamos e propomos o em notação BPMN os Modelos de Processo dos Protocolos de Triagem (bem como suas respectivas Descrições de Processo) dos quatro protocolos de triagem abordados nesse trabalho.

Conjunto de Recomendações para BPMN: Considerando as validações dos modelos de processos em BPMN realizadas com os profissionais de saíde, nós reportamos e discutimos um conjunto de sugestões sobre BPMN para a representação de protocolos de triagem.

Como contribuições secundárias, destacamos que nosso trabalho também disponibiliza o conjunto descriptive dos questionários online aplicados aos profissionais da saúde, bem como o processo de seleção e entrevista aplicados no nosso tralho como forma de viabilizar que futuros pesquisadores reproduzam nosso estudo em diferentes realidades e contextos, construindo um corpo empírico de conhecimento científico sobre o campo de pesquisa.