Chapter 17
Leading the Emergency Department as a Complex Adaptive System

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Healthcare is a convoluted system with a large number of opportunities and challenges. No matter what administrative task is performed, interdependencies of people, resources and processes are everywhere. Many times services provided are not achievable as originally expected. Due to the business complexity, it is often difficult to identify what is the cause of the inefficiency. Performance metrics can be defined and measured without having a good understanding of the factors that generated those metrics. This has an impact on the value of health systems interventions because no clear cause of benefit or costs can be associated to the intervention outcomes. Another instance are initiatives to integrate healthcare, which are faced with limited success to reduce costs and bring substantial improvements in healthcare delivery. These are some among many examples where health systems' complexity requires application of a different perspective in its administration and leadership.

The need to apply alternative approaches to the administration and leadership of the healthcare organization has been identified as a key factor to tackle some of the healthcare management challenges [1–4]. Lately these challenges are becoming larger as a result of increase demand for health services, rising costs, and patient needs for the best care delivery [5, 6].

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Recently the use of Systems and Complexity Sciences has been identified as a viable methodology to understand and manage the challenging health care system from a variety of perspectives including human health, health services, and the health care organization [7, 8]. In short, Systems and Complexity Sciences aim to understand how things are connected with each other, and how these interactions work together. Complex Adaptive Systems (CAS) is a branch of Systems and Complexity Sciences, which is the study of adaptive systems [9]. CAS is an interdisciplinary field that brings a different perspective to help lead healthcare organizations. CAS concepts of non-linearity, interdependencies, adaptability and emergence are applicable to health system administration and provide a relatively novel approach to manage healthcare organizations.

In this chapter, we discuss the identification and application of CAS concepts to the administration and leadership of the health care organization. Four fundamental CAS concepts are discussed to introduce the CAS paradigm and facilitate the assimilation towards the management of the healthcare organization. The Emergency Department (ED) is utilized as a case study to analyse and identify the application of CAS concepts. The ED has become an important component of the health organization as an entry point for a large number of patients into the hospital and provider of primary care [10]. CAS concepts are briefly described in Sect. 17.1, followed by a discussion of the main ED participants in Sect. 17.2. The relationships and information exchanges among these participants create a network of relationships that form an ED system that is responsible to provide health care services. Section 17.3 examines how to position the ED organization to a CAS perspective. The case study facilitates the understanding of CAS concepts and their applicability to other health care organizations and departments. Section 17.4 concludes with some final thoughts on the next steps for the use of CAS on the healthcare organization and how these ideas can be extended beyond the ED organization.

17.1 Complex Adaptive System Concepts

There are several CAS concepts that are relevant to a healthcare organization. The following concepts of non-linearity, interdependencies, adaptability and emergence are briefly described from an organizational perspective. Despite other applicable CAS concepts [11, 12], our approach suggests to begin with these four fundamental concepts and learn about their implications on the organization. This assists the initiation of thinking and managing the healthcare organization from a CAS perspective.

Non-linearity is a widely used term in mathematics to infer a relationship that is not of first degree or linear. For instance, a variable y with a linear relationship to another variable x implies that when the value of x changes, the value of y will proportionally change, i.e. there is a linear change. When there is a non-linear mathematical relationship, then a change in the value of x will generate a change in

the value of *y* that is not proportional. The change in *y* can be much larger or smaller than the change of *x*. If we empirically translate the concept of non-linearity to the healthcare organization, it implies that people actions and their relationships among themselves can have large or small impacts on the outcomes of the organization. Sometimes it is desirable to have a large impact when an action is carried out (e.g. a well-intended health system intervention to increase patient safety), but sometimes it is the opposite that is desirable to minimize impact (e.g. when a key staff leaves the organization). A key challenge for leaders is how to identify the actions and relationships within the organization that can have the desirable impact level.

Interdependencies is another critical CAS concept. We all know that we live in a highly connected world where everybody and everything depends on each other to some extent. This has become more apparent with the proliferation of the Internet in the last two decades that has made readily and speedily the access of information. It does not matter what view is utilized: financial, environmental, societal, etc.; we are all connected from a variety of perspectives creating a mesh of interdependencies that are difficult to understand in base of their strengths and effects. Healthcare organization interdependencies exist internally and externally. A hospital is affected by interdependencies with government (e.g. policies), insurance companies (e.g. coverage policies), medical groups (e.g. clinical protocols), vendors (e.g. biomedical technologies), staff (e.g. skills), patients (e.g. pandemics), etc. All these participants carry out actions and relationships that create interdependencies to a variable strength and influence.

Adaptability is particularly relevant to healthcare. Adaptability is defined as the capacity of the organization to change and continue providing services relatively at the same desired level when internal or external conditions vary. For instance, humans frequently adapt to changing conditions. It is common to plan activities, and have those activities change to manage current conditions. At the hospital, every day is different bringing a variety of tasks with diverse needs of care and service. Traditionally the healthcare organization has been adaptable to some extent, for instance, adjusting work-flows to manage changes in service demand and requirements, but meanwhile following standard protocols of care. However, this has recently changed in many health settings because of a variety of factors like increasing demand, resource constraints, limited staff, complex conditions, etc. All these varying conditions expose the adaptability capacity limitation of some organizations. For instance, in Canada we observe a variety of ED wait times across the nation [13] demonstrating how well different settings are adapting when they face varying conditions. For fairness in our discussion, we acknowledge that those varying conditions are not necessarily the same among health settings, hence we can expect different ED wait times across the country.

Emergence is perhaps one of the most important CAS concepts. Emergence is technically defined as the appearance of system properties coming out of the activities and relationships among system components. Intuitively, emergence assists to provide an explanation of how it is possible to achieve properties at a systems level. From a healthcare organizational perspective, actions and relationships carried out among stakeholders produce emergent properties. In the ED case, the activity and

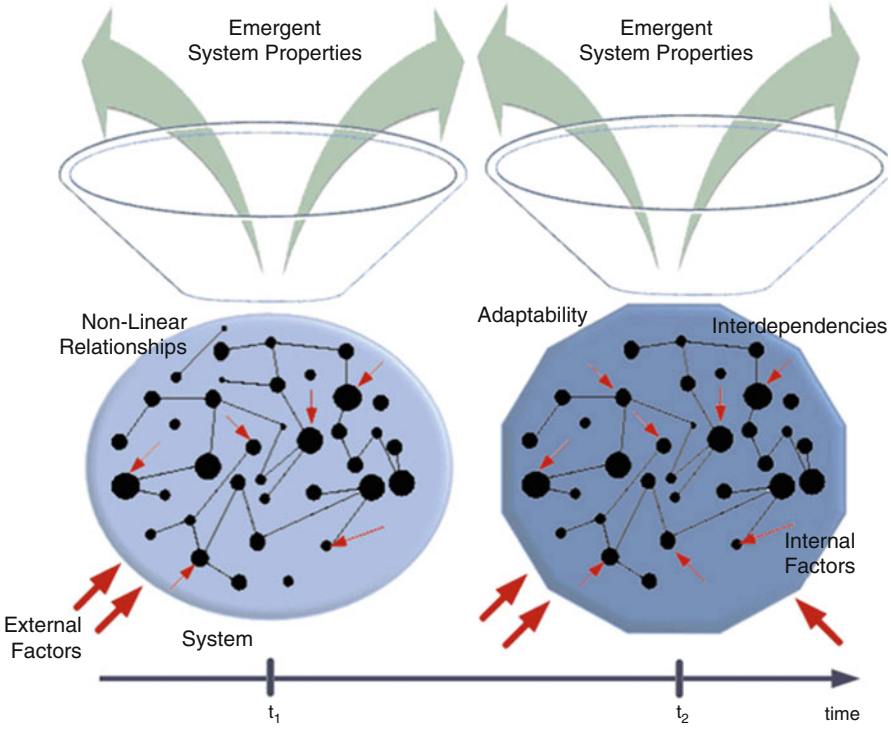

Fig. 17.1 Integration of CAS concepts

relationships among ED participants described in Sect. 17.2 together with internal and external factors give rise to a series of system properties, which are usually measured from a variety of metrics. Samples of ED emergent system properties are ED length of stay, ED re-admission rates, time to physician initial assessment (PIA), number of medical misdiagnosis, etc. It is not an easy task for organizational leaders to properly identify the components that give rise to a given emergent system property. In the ED case, besides participant actions and relationships, external and internal factors like facility type and location, age and sex distribution of patients, and condition severity are some of many factors that can also influence the emergence of the ED system property.

Before applying CAS concepts into the ED case, an understanding of how the four concepts integrate is required. Figure 17.1 outlines a simplified view of how the concepts connect to each other in a given system.

The system under study is located inside the circle of Fig. 17.1 with its components (solid dots) carrying out actions and relationships. These activities produce a mesh of interdependencies and non-linear relationships (solid links among dots). The system exists within a larger ecosystem with external and internal factors (red arrows) influencing the system components thereby their actions and relationships;

and consequently their interdependencies and non-linearities. The set of actions, relationships, interdependencies, and non-linearities generate emergent system properties that characterize the system as an entity (large arrows emerging from the circles). The emergent properties will provide the system the adaptability to internal and external factors that continuously change, i.e. the system view on the right circle (time = t_2) is adapting to new factors and interdependencies, but still providing the same or equivalent emergent system properties as the system view on the left circle (time = t_1).

17.2 The Emergency Department System

ED participants play a variety of roles critical to the success of the ED as a system. The ED is considered a system within a larger system (e.g. a hospital) with its own properties emerging from the actions and relationships of its participants (i.e. components). For instance, ED wait times from the time people arrive until the time they are discharged or admitted to the hospital is a system property that emerges from the actions and relationships of the ED participants. Other ED system properties are defined later in Sect. 17.3. Although there are other system components, in our analysis we consider two main system components for the ED case: human participants and information technology. Human participants' actions form relationships among the participants creating a network that produce the system property of interest (e.g. length of time people spent in ED). Information technology is a component tool that facilitates the communication and information exchange among human participants. Suitable information technology in place can substantially influence how the human participants perform their actions and the relationships they have with other participants, thereby also affecting the ED system properties emerging from it (e.g. ED wait times). Table 17.1 lists ED human participants and briefly outlines their actions and roles. Table 17.2 lists ED information technology.

Human participants roles and actions (Table 17.1) give rise to a rich variety of interactions and scenarios. A representative sample of the set of interactions is listed in Table 17.3. The interactions will create interdependencies among those human participants with non-linear affects. These interactions are influenced by the use of information technology tools (Table 17.2). The influence can impact the interdependency and non-linear effect observed out of a given interaction.

17.3 Applying Complex Adaptive Systems into the Emergency Department

Figure 17.1 is a simplified depiction of reality. A system can be seen from a variety of perspectives. One approach is to have a perspective based on the emergent system

Table 17.1 ED system human participants

Human participant	Main actions performed
Triage nurses	Triage nurses decide the order in which patients are to be evaluated by physicians. Once the patient arrives the triage staff makes a clinical assessment of the patient along with vitals. This ultimately results in the patients being categorized into a triage category. The triage category along with the ED volume will affect the time interval between being seen in triage to being seen by a physician [14]. Registration also occurs simultaneously or in sequence, and the patient's demographic and identifying data is taken down into most commonly an electronic patient tracking system
ED nurses	After the patient is triaged and brought into a room, an ED nurse is assigned to a patient or patients in the assigned area. Depending on ED volume and staffing numbers, nursing staff will take care of varying numbers of patients at one time. The nurse will do re-assessments and monitor the clinical status of patients at regular intervals. Along with this, they also, carry out physician orders (i.e. phlebotomy, IV line placement, administration of fluid and medications). Nurses also provide assistance for procedures performed in the ED, patient education and look after the general comfort of the patients
Attending physicians	Attending physicians in the ED identify the following themes of collaborator, communicator, collection of information, and quality of care along with attending to patients as their main actions. ED physicians begin and end their shift with communicating and collaborating in transfer of information between other ED physician staff. This is an important process as the new oncoming ED staff will then inherit patients that require ongoing care and will need to attend to them along with the new incoming patients. The attending staff collects information through their interactions with other ED staff (i.e. nurses, residents, consultants, etc.) as well as from information technology to obtain key information on the patients they are providing care for. The attending physician teaches and collaborates with the learners they are supervising meanwhile coming up with a patient management plan. Collaboration and communication with other consultants of a variety of specialities through phone calls or in person is also required given the wide range of presenting patient complaints. Overall, it has been shown that most of a physician's time in the ED is spent on multitasking [14]
Learners (teaching hospital setting—residents, medical students)	Learners will evaluate and assess patients to decide on a possible diagnosis and ultimately a plan of management. The learner's responsibility is then to formally present the patient to the attending physician and propose their findings and management plans. Together, the learner and the attending physician devise a final management plan to provide patient care. One of the learner's major roles and challenges is the role of learning. They must look up information when posed with the unknown, receive teaching from their attending staff, and must get accustomed to the environment. The work-flow of the resident closely reflects that of the attending physician

Consultants	ED physicians must collaborate with consultants representing the various disciplines of medicine, transfer information about the patient, and if chosen to be admitted, a transfer of care. Consultants assess patients in the ED and play a role in the patient's management by either choosing to admit them, follow them or by providing advice on care to the ED physician
Desk clerks	The desk clerk manages all clerical duties in the specific area. Usually each treatment area (i.e. major, intermediate, minor) has its own desk clerk. Desk clerk duties include making phone calls for physicians, keeping track of patient flow, and paperwork duties
Technicians (laboratory technicians, radiology technicians)	Technicians are often available throughout the day, and deliver services when called or orders are filled. The ED is highly dependent on the efficiencies of other departments as lab and radiology. Without their services, the physician's management plan is difficult to follow and the efficiency of the ED is negatively impacted [14]
Health care workers	Health care workers move patients around the emergency room, and ensure that rooms are prepared and cleaned between patients
Social workers	Social workers help patients with social issues like housing, financial, and finding other resources that are unique to each patient's needs. Very beneficial during working hours, but often some ED do not have around the clock social workers and often their services are only available during certain times of day

Table 17.2 ED system information technology

Information technology	Main actions performed
Electronic Patient Record (EPR) system—or equivalent	An electronic record system provides retrieval of information on patients, ability to check for laboratory test results, or admission and discharge information. In some hospitals EPR is also used for documentation, consultation, and order input as related to a patient
Drug Program Information Network (DPIN) system—or equivalent	DPIN is an electronic, online, point of sale drug system to support the patient drug management. DPIN system stores, manages, distributes, and provides access to patient medication data
Radiology Information System (RIS)/Picture Archival and Communication System (PACS)—or equivalent	RIS/PACS is an electronic system used by radiology and medical groups to store, manage, distribute, and provide access to radiology reports and imaging
Labs Information System (LIS)—or equivalent	LIS is an electronic system used by laboratory operations and medical groups to store, manage, distribute, and provide access to patient (inpatient, outpatient) laboratory tests processes and results

Table 17.3 ED interaction/scenario sample

Interactions/scenarios
Patients entry into the ED is either through walk-in, Emergency Medical Services (EMS), or transfer from another hospital/area
• Patients that are walk-ins are then triaged on entry, and then will be seen based on triage category
• Patients coming in through EMS or transfer process are usually pre-triaged either by EMS or by staff doing the transfer
Once patient is within the ED they are provided care from
• Nursing staff and are evaluated by either attending physician, resident, and/or medical student through a history and physical exam
• Then diagnostic investigations (imaging, laboratory work) are carried out depending on entrance complaint and data gathering carried out by evaluating staff
Consulting services are called/notified if a patient needs to be admitted to a specific service, or if more specific expertise is needed in their specific field. The patient ultimately being admitted to a floor, transferred to a different facility or discharged home with follow-up
• Bed availability is often a rate-limiting component of the scenario
House staff use resources (technology and non-technology) for decision making:
• clinical information systems that provide access to laboratory information, patient's previous medical history including results of previous investigations (imaging and lab work) and previous physicians and nurses notes
• paper charts
• telephones to consult services for consults or advice
• lab delivery system and imaging
• auxiliary forms
At the end of the shift, the attending physician must do "handover" with the new attending physician coming on and his/her team
• Shift change is when the majority of information transfer occurs, and the process is usually conducted in either a form of "sit down rounds" or "walk rounds"

property under study. Two system properties are described next as examples of emergence coming out of the actions and relationships active at the ED system. Figure 17.2 shows a sample of the ED time-based system properties and how they relate to each other.

Wait Time for Physician Initial Assessment—Once the patient enters the ED they are initially triaged based on their level of acuity[1] and registered for patient name, demographics, etc. Based on the patient's acuity level, they will be triaged and this will affect the order that they are seen in the ED. Patients with lower CTAS scores (1, 2) are often seen very quickly, versus those with scores of (3–5) may have to wait longer depending on the volume of patients already present at the ED [15]. The triaging designator (usually a nurse triage) plays an important role in

[1]Canadian Emergency Department Triage and Acuity Scale (CTAS) system is the most commonly used triage scoring system in Canada.

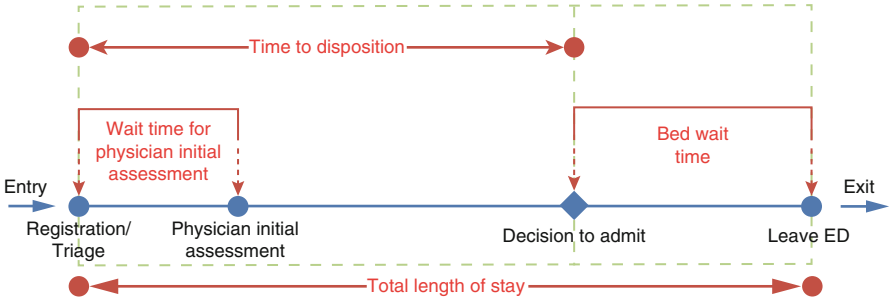

Fig. 17.2 System properties related to wait times

ultimately deciding the order that the patients will be seen, and accuracy is of utmost importance. The time measured here is from initial ED registration/triage to the point when the physician does their initial assessment. In this instance we observe various participants (triage nurses, attending physicians, learners, desk clerks, health care workers, etc.) carrying out actions and relationships with the assistance of information technology tools. All these activities with their interdependencies and non-linear relationships will give rise to the Wait Time for PIA observed at the ED. The ED system adaptability can be observed on scenarios where service demand exists for a large number of patients with a specific acuity (e.g. many patients with low CTAS scores). The ED will be adaptable up to a certain level to the external factor of increase demand of services. At some point of demand, the Wait Time for PIA is affected substantially unless other logistic measures are taken.

Time to Disposition—Disposition in the ED refers to the point in time when the assessment for the patient has been completed and the final plan decided. Disposition is usually either the decision to admit to the hospital or to discharge home with or without follow-up at an outpatient department. The time to disposition includes from the point the patient enters the ED after triage/registration to the point when a final disposition plan is made by the attending physician [16]. During this period of time, history and physical assessments are made by nurses, learners (if at a teaching hospital), and physicians. Diagnostic procedures are ordered which can include laboratory and imaging investigations. As well old patient information is often retrieved through either an electronic medical record or if old documentation not available on electronic system it is often requested from another location. Interventional procedures and treatment are often begun in the ED. All these actions are to eventually be able to make the decision whether the patient will need to be admitted, discharged, or need further re-assessment/second opinion. This system property has a more complex perspective compared to others because more ED participants and tools can take part. Similarly a large number of interdependencies and non-linear relationships exist that contribute to the system property of Time to Disposition.

ED system properties are also affected by external and internal factors (Fig. 17.1). For example, evidence from other studies has shown that system properties are

affected by the patient's age, gender, acuity of problem, whether registered through the ambulance or a walk-in, and the time of day that the patient presents [13]. Of course, high acuity patients that present to the ED will have lower wait times to be initially assessed, but studies have shown that they have overall higher total ED Length of Stay (LOS[2]) durations. Similarly, the Canadian Institute for Health Information [13] shows that although patients who end up being admitted vs. their non-admitted counterparts have lower initial wait time assessment, they have longer total ED LOS. It has also been shown that these system properties are variable on the type of ED that is involved. The duration of time that patient's wait appears to vary on geographical location, rural vs. urban, as well as teaching vs. non-teaching hospitals. It has been noted that urban teaching hospitals tend to have higher volume of patients presenting to the ED, and this seems to correlate with a higher number of more acutely ill patients. All these provide evidence of large number of factors (internal, external) besides system participant actions and relationships that contribute to the system properties emerging. In the study of a system from a CAS perspective, many system properties can be examined. For the ED case, some other system properties that may be relevant for the ED administration can include

- Bed wait time[3]
- Number of patients seen per day
- Number of patients discharged, admitted
- Number of patients LWBS (Leave Without Being Seen)
- Number of patient recidivism (patients that frequently visit ED in short durations)
- Number of medical errors per day/week/month/year

17.4 Extending the Use of Complex Adaptive Systems Beyond the Emergency Department

This chapter has focused on understanding the fundamentals of CAS concepts of non-linearity, interdependence, emergence, and adaptability as a method to introduce a CAS perspective in the management and leadership of health systems. The ED has been discussed as an instance to exemplify how the CAS concepts can be applied. The goal is to start building the bridge that facilitates the use of concepts and methodology from Systems and Complexity Sciences into the Health Sciences realm.

In Sciences, a general approach to increase our understanding of the realm is to create models and simulate/experiment their behaviours. Most common methods to

[2]Length of Stay (LOS) is the duration of time that the patient stays within the ED from the point of registration/triage to the moment of disposition and leaving the ED.

[3]Bed wait time begins from the point the disposition plan is to admit a patient to the point the patient leaves the ED to the ward when a bed is available.

carry out the general approach include: laboratory experiments and/or field studies; mathematical formulations; and computer modelling and simulation. Currently, most of the CAS research is done with computer modelling and simulation [17–19]. Mathematics can be quite complex when dealing with large number of system components. Similarly laboratory experiments and/or field studies may not be possible or limited in scope for the same reasons. Instead, computer modelling and simulation provide flexibility and scalability for scenarios and have become a common approach to study CAS.

Creating a proper computer model for the system under study can however be challenging. Critical to the success is to choose the correct participant actions and relationships giving rise to the desired system properties. Understanding and applying the CAS concepts assist to identify the key actions and relationships to create better computer models for the system under study.

Future work will expand this initial study to develop methodology to extend CAS concepts and apply them in building computer models and simulations. The computer models and simulations will help evaluate healthcare interventions, and assist identifying causes and benefits from a holistic perspective. Better healthcare interventions can substantially improve the impact of policies on our health system. Computer modelling and simulation with a CAS perspective can provide an alternative approach to lead and manage health systems in the twenty-first century.

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