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A Comprehensive Key Performance Indicators Dashboard for Emergency Medical Services

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***Abstract*—**The present study aims to develop a dashboard of Key Performance Indicators (KPI) to enhance information and predictive capabilities in Emergency Medical Services (EMS) systems, supporting both operational and strategic decisions of different actors. The employed research methodology consists of a first phase of revision of the technical-scientific literature concerning the indicators currently in use for the performance measurement of EMS. It emerges that current studies focus on two distinct areas and independent objectives: the ambulance service, a fundamental component of pre-hospital health treatment, and the patient care in the Emergency Department (ED). Conversely, the perspective proposed by this study is to consider an integrated view of the ambulance service process and the ED process, both essential to ensure high quality of care and patient safety. Thus, the proposal covers the end-to-end healthcare service process and, as such, allows considering the interconnection between the two EMS processes, the pre-hospital and hospital ones, connected by the assignment of the patient to a specific ED. In this way, it is possible to optimize the entire patient management. Therefore, attention is paid even to EMS aspects that in current literature tend to be neglected or underestimated. In particular, the integration of the two processes enables to evaluate the advantage of an ED selection decision having visibility on EDs' saturation status and therefore considering, besides the distance, the available resources and the expected waiting times. Starting from a critical review of the KPIs proposed in extant literature, the design of the dashboard was carried out: the high number of analyzed KPIs was reduced by eliminating firstly the ones not in line with the aim of the study and then the ones supporting a similar functionality. The KPIs finally selected were tested on a realistic dataset, which draw us to exclude additional indicators due to unavailability of data required for their computation. The final dashboard, that was discussed and validated by experts in the field, includes a variety of KPIs able to support operational and planning decisions, early warning, and citizens' awareness on EDs accessibility in real time. The association of each KPI to the EMS phase it refers to enabled the design of a well-balanced dashboard, covering both efficiency and effectiveness performance objectives of the entire EMS process. Indeed, just the initial phases related to the interconnection between ambulance service and patient care are covered by traditional KPIs. Future developments could be directed to building a hierarchical dashboard, composed by a high-level minimal set of KPIs for measuring the basic performance of the EMS system, at an aggregate level, and lower levels of KPIs that bring additional and more detailed information on specific performance dimensions or EMS phases.

***Keywords*—**Emergency Medical Services, Key Performance Indicators, Dashboard, Decision Support.

I. Introduction

MEASURING the performance of EMS is essential to provide timely and effective treatment to patients. To this end, it is necessary to rely on a comprehensive set of KPIs able to cover all the significant EMS objectives and activities, thus supporting operational decisions of healthcare managers, as well as strategic decisions at health system level.

The approach adopted in this study is the orchestration of the entire EMS process: from the transport of the patient with an ambulance, to the medical evaluation in the ED, to the final patient disposition and departure from the ED. Starting from this vision and through a systematic review of the literature, a KPI dashboard is proposed to respond to the following uses:

- Operational (ED selection decision for patients requiring ambulances): this use is supported by KPIs measuring the resources saturation/availability and the case mix of patients present in a specific ED.
- Planning: this use is supported by KPIs related to resources consumptions, type of treatments, effectiveness and efficiency performances, etc.
- Early warning: this use is supported by KPIs able to early detect the onset of events to be monitored (e.g. epidemics, high inflow of patients).
- Information to citizens: this use is supported by KPIs that improve the accessibility to EMS systems for the entire community by providing real time information about the EDs status.

The resulting dashboard is then tested on a realistic dataset of Lombardy Region, Italy, with a double purpose: on the one side, to evaluate the contribution that each KPI could bring in a real context; on the other side, to investigate if the current data recording of Lombardy Region is sufficient to monitor the entire EMS efficiency and effectiveness.

The paper is organized as follows: after having described the methodology adopted for this research, a brief review about the KPIs currently used in the EMS domain will be presented. The subsequent section will be focused on the description of the steps undertaken to develop the dashboard. Finally, the paper ends with the main conclusions and future developments of the work.

II. Research Methodology

The research methodology adopted in this study includes the

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following steps:

1. Literature review to gather information about the KPIs currently used to measure and evaluate the performances of EMS systems;
2. Identification of new KPIs for improving the management of EMS, based on the gaps emerged in literature;
3. Development of a comprehensive dashboard able to monitor all the different phases of EMS systems.
4. Test of the dashboard of KPIs on a realistic dataset.

III. Literature Review

The literature review about KPIs used in EMS domain was performed on Scopus through the following research formula: *("emergency department" OR "emergency medical service") AND (health* OR hospital*) AND (KPI OR indicator* OR performance)*.

It emerged that the current studies are focused on the ambulance service or on the ED process, which are considered as two separated components of the EMS systems.

A. Ambulance Service KPIs

Ambulance service is an essential component of pre-hospital health treatment, which includes the following phases (Fig. 1):

1. Call at operations center that activates an ambulance to be sent to the event location.
2. Pre-hospital care at the event location. At the end of this phase, the medical staff of the ambulance evaluates the need to transport the patient to an ED; phases 3 and 4 are not taken into account if the transport to an ED is not required.
3. Hospital selection decision to assign the patient to the most proper ED.
4. Ambulance load-off.
5. Ambulance relocation to a predefined base or to a new event location.

Scientific literature [1]-[3] revealed that the KPIs used to evaluate the performance of ambulance service (Table I) are mainly focused on the first two phases of the process, overlooking important aspects of the subsequent phases.

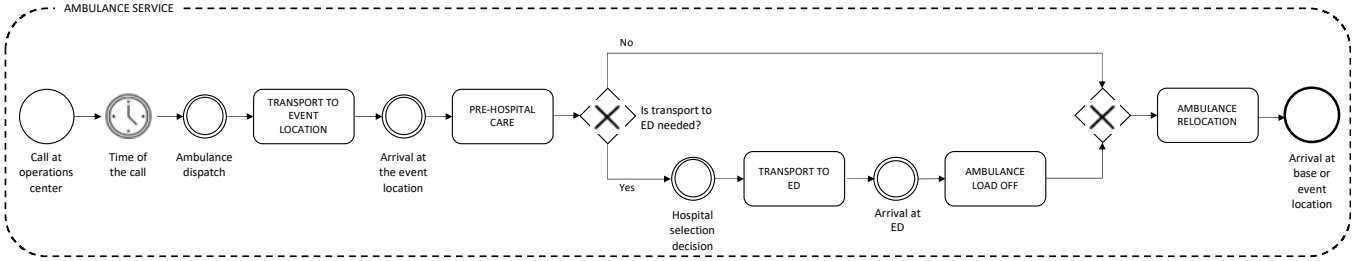

Fig. 1 Ambulance service process

TABLE I
AMBULANCE SERVICE KPIS

KPI	Definition	Reference
Response time	Time from the call received at the call center to the ambulance arrival at the event location.	[1], [2]
Response effectiveness	Percentage of patients waiting for the ambulance less than 8 minutes. A 100% value of the KPI implies that the 8 minutes response time standard is fully met.	[3]
Workload	The KPI can be computed as: • Number of patients with high priority needs; • Number of critical patients that require immediate intervention; • Number of interventions that require an advanced vehicle.	[3]
Resources availability	The KPI can be computed according to the different resource categories: • Availability in unit hours of basic and advanced vehicles; • Staff availability; • Equipment availability.	[1], [2], [3]

B. ED Process KPIs

The ED process includes the following phases (Fig. 2):

1. Arrival of the patient to the ED.
2. Welcome and triage, with the patient identification and the assignment of a priority code (Table II).
3. Clinical evaluation, which includes the medical examination of the patient and the stabilization of his clinical conditions. At the end of this phase, a code is assigned to express the degree of criticality of the patient (Table III).
4. Disposition, which can result in:
   a. Discharge;
   b. Observation;
   c. Admission within a ward of the hospital;
   d. Transfer to another healthcare facility.
5. Departure, where the patient leaves the ED following the path previously established by the disposition.

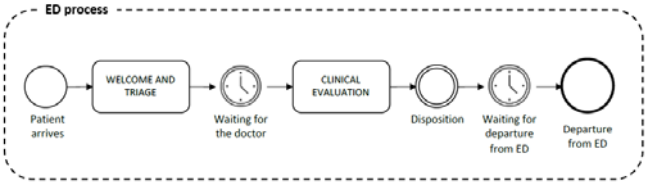

Fig. 2 ED process

By analyzing information from scientific literature, it is possible to identify the following categories of KPIs used to measure the effectiveness of ED service [5]:

- Patients flow: KPIs that enable to monitor the ED arrivals, considering the totality of patients or specific groups of them. Table IV shows the list of KPIs of this category.
- Time interval: KPIs that enable to monitor the duration of the service phases. Table V shows the list of KPIs of this category.

TABLE II
PRIORITY CODE ASSIGNED DURING TRIAGE

Triage code	Classification [4]
Red	Emergency: one or more vital functions interrupted or compromised
Yellow	Urgency: risk of vital functions compromised or severe pain
Blue	Deferrable urgency: stable condition without evolutionary risk that requires complex interventions
Green	Minor urgency: stable condition without evolutionary risk that requires simple interventions
White	Non-urgency: problem of a minimal clinical relevance

TABLE III
CRITICALITY CODE ASSIGNED AT THE END OF THE CLINICAL EVALUATION

Criticality code	Classification [4]
Red	Critical patient: one or more vital functions interrupted or compromised
Yellow	Acute patient: stable condition with a potential degeneration of vital parameters
Blue	Patient with deferrable urgency: stable condition that requires complex non-immediate interventions
Green	Patient with minor urgency: stable condition that requires simple non-immediate interventions
White	Non-urgent patient: therapy can be scheduled in time

TABLE IV
PATIENTS FLOW METRICS

KPI	Definition	Reference
ED census	Number of daily patients arriving to the ED, with the possibility of specifying the rate per morning, evening and night.	[5]-[8]
Patients waiting for clinical evaluation	The current number of patients present in the ED waiting for the first medical observation (including those on stretchers, on chairs, in hallways and in waiting room).	[5], [7], [9]-[13]
ED acuity	Percentage of arrivals divided by triage acuity (i.e. triage code).	[5], [6], [14]
ED age mix	Percentage of arrivals divided by the following categories: • Infant, 0-2 years; • Pediatric, 3-18 years; • Adult, 19-64 years; • Geriatric, 65-80 years; • Elder geriatric, >80 years.	[6]
ED case mix by diagnosis	Percentage of arrivals divided by ICD (International Classification of Diseases) code assigned after the clinical evaluation.	[6]
Left without being seen	Total number of patients who leave the ED before examination by a physician, divided by the total number of patients who presented to the same ED during a defined time period.	[5]-[7], [10], [14]-[17]
Left before treatment completion	Total number of patients who leave before treatment was completed, divided by the total number of patients who presented to the same ED during a defined time period.	[6], [17], [18]
Admission rate	Percentage of patients admitted, divided into: • Intensive care unit admission rate; • Hospital floor admission rate; • ED observation unit admission rate.	[6], [10], [17], [18]
Transfer rate	Percentage of patients transferred to another inpatient facility.	[6], [17], [19]
Medical fit for discharge	Number of patients who have finished the first clinical evaluation and do not need further treatment.	[13]
Unallocated patients with decision to admit	Number of patients that have finished the clinical examination, not discharged, but waiting to be admitted to the hospital, thus occupying resources.	[13]
Inpatients rate	Percentage of patients in ED that have been admitted but have not been transferred to ward due to lack of bed availability.	[9]
One-to-one patients	Number of patients undergone to ventilator. In case of unavailability of the data, it can be approximated by the number of patients with a red triage code for less than three hours.	[26]
Crowdedness index	Ratio between the current loading of ED (i.e. medical resources occupied by all patients currently present in the ED, approximated by the number of patients in ED) and the full capacity of ED. Differentiating the patients based on their length of stay in the ED, the KPI allows identifying the cause of overcrowding: • Patient flow: ratio between the number of patients with a length of stay lower than 24 hours, and the full capacity. • Non-allocation type 1: ratio between the number of patients with a length of stay between 24 and 48 hours, and the full capacity. • Non-allocation type 2: ratio between the number of patients with a length of stay higher than 48 hours, and the full capacity.	[20], [26]
Patient flow index	Ratio between the number of patients arriving to the ED in the specific day and the 91st percentile of the patients historically arrived to the ED (calculated on the arrival distribution of the previous year).	[26]
NEDOCS	Evaluation of the ED saturation status considering the following potential situations: • Calm: operators are busy but not overloaded; • High load: operators are loaded but the ED status is still manageable; • Overcrowding: the request for healthcare services exceeds the availability; • Critical overcrowding: the ED is in a critical situation; • Extreme overcrowding: the ED is close to collapse.	[26]

- Resources: KPIs that enable to monitor the available resources in the ED. Table VI shows the list of KPIs of this category.
- Quality: KPIs that enable to monitor the effectiveness of the service offered by the ED. Table VII shows the list of KPIs of this category.
- Cost: KPIs related to the number and the type of healthcare treatments provided to the patients. This category will not be further investigated since it is not part of the uses for which the dashboard has been developed.

The information collected from literature were integrated with the KPIs present on Emergency Urgency OnLine (EUOL)

system adopted in Lombardy Region, which is an information sharing platform used by hospitals and ambulance operations centers.

TABLE V
TIME INTERVAL METRICS

KPI	Definition	Reference
Load-off time	Time interval between patient arrival in ambulance and the transfer of care to ED staff.	[21]
Length of stay	Time interval between the arrival in ED and the physical departure by the ED. This is tracked for the following subsets of patients: • Admitted patients; • Discharged patients; • Transferred patients.	[5]-[10], [14], [16]-[18], [21], [22]
Length of stay index	Ratio of the actual length of stay by the theoretical length of stay for the non-urgent patients.	[11]
Time to triage	Time interval between the arrival in ED and the beginning of triage process.	[5], [7], [18], [23]
Time to nursing assessment	Time interval between the arrival in ED and the initial nursing review.	[11], [15], [23]
Arrival to treatment space	Time interval between the arrival in ED and the placement in an ED treatment space.	[6], [15], [17]
Door to doctor	Time interval between the arrival in ED and the first provider contact (examination by a physician). The KPI can be tracked distinguishing patients by triage code.	[5]-[7], [10]-[12], [14], [16], [18], [21], [22], [26]
Triage to provider	Time from assignment of triage category to the first medical examination.	[9]
Treatment space to provider	Time interval between the placement in an ED treatment space and the first provider contact (examination by a physician).	[6]
Provider to disposition	Time interval between the first provider contact and the disposition order. According to the disposition, the KPI can be calculated as: • Doctor to discharge: the time interval between medical doctor contact with the patient and discharge. • Doctor to decision to admit: the time interval between medical doctor contact with the patient and the decision to admit. • Doctor to decision to transfer: the time interval between medical doctor contact with the patient and the decision to transfer to another facility.	[6], [14], [17], [18], [21]
Disposition to departure	Time interval between the disposition order and the physical departure from the ED. According to the disposition, the KPI can be calculated as: • Admit to departure: time from the admission decision to the departure to floor. • Transfer to departure: time from the transfer decision to the ambulance diversion.	[5], [6], [9], [21], [23], [26]
Time in observation	Average time spent in observation in the last 48 hours.	[26]

TABLE VI
RESOURCE METRICS

KPI	Definition	Reference
Physician hours	Total number of physician hours per 100 ED visits.	[6]
Nursing hours	Total number of direct care clinical nursing hours per 100 ED visits.	[6]
Patient-Doctor ratio	Ratio of the number of patients present in the ED by the number of physicians.	[10], [11], [18]
Patient-Nurse ratio	Ratio of the number of patients present in the ED by the number of nurses.	[10], [18]
Number of beds	Number of beds specifying the available, extra, occupied and reserved ones.	[5], [9]
Stretcher occupancy	Percentage of ED stretcher hours/day occupied by inpatients.	[21]

IV. DASHBOARD DEVELOPMENT

The novelty brought by this study, compared to the current dashboards of indicators used in the context of EMS, is represented by the use of an integrated vision of the ambulance service process and the ED process (Fig. 3), both essential in guaranteeing quality performance to the patient. Consequently, the evaluation of the EMS system takes on a new perspective based no longer on the individual components of the process, but on the overall performance of the entire process and according to a patient-centered view. To include this view, an indicator has been defined, called Patient Throughput Time, which will be calculated in two different ways:

1. Net Patient Throughput Time: time between the start of the journey to the ED and the disposition.
2. Gross Patient Throughput Time: time between the start of the journey to the ED and the departure.

This new perspective makes it possible to evaluate the advantage of an ED selection decision having visibility on EDs' saturation status and therefore considering, besides the distance, the available resources and the expected waiting times.

Further KPIs were also introduced to fill the gaps that emerged in the literature:

- ED case mix by problem: percentage of arrivals divided by main problem assigned at the time of triage, according to the classification provided by the Ministry of Health [25].
- ED case mix by mode: percentage of arrivals divided by arrival mode (autonomous or with emergency vehicle).
- Travel time: time between the start of the ambulance journey to the ED and the arrival at the ED.
- Provider to departure: time between the start of the clinical evaluation and the actual departure of the patient from the ED.
- Triage code appropriateness: appropriateness of the assignment of the priority code assigned during triage compared to the criticality code assigned at the end of the clinical evaluation.

Starting from these considerations, the most appropriate KPIs were identified to respond to the different uses (i.e., operational, planning, early warning, information to citizens) following the logic shown in Fig. 4. In particular, from the 52 indicators identified by the literature analysis, a process of exclusion began following various criteria:

1. Exclusion of KPIs not in line with the objectives of the study:
a. The whole KPI category of ambulance service (they focus only on the response following the call).
b. The whole cost category.
c. Among the patients flow metrics: *ED age mix* and *One-to-one patients*.
d. Among the time interval metrics: *Time in observation*.

TABLE VII
QUALITY METRICS

KPI	Definition	Reference
Unplanned re-attendances	Ratio between the number of patients that enters the ED within *n* days following an ED discharge, and the number of patients discharge in the reference period.	[5], [6], [15], [17], [19]
Position index	• Percentage of arrivals with green criticality code and admitted to ward; • Percentage of arrivals with yellow criticality code and discharged; • Percentage of arrivals with red criticality code and discharged; • Percentage of arrivals with white triage code and white criticality code.	[24]
Performance index	• Percentage of arrivals with white triage code and white criticality code that do at least two medical examinations; • Percentage of arrivals with green triage code and white criticality code. • Percentage of arrivals with yellow triage code, white criticality code and admitted to ward; • Percentage of arrivals with red triage code, white criticality code and admitted to ward.	[24]
Data consistency index	• Percentage of arrivals with white criticality code and admitted to ward; • Percentage of arrivals with disposition “left without being seen” and criticality code “not applicable”; • Percentage of arrivals with red triage code and disposition “arrived as corpse”; • Percentage of arrivals with black triage code and disposition “arrived as corpse”; • Percentage of arrivals with white triage code and white criticality code that are undergone to a single medical examination; • Percentage of arrivals with disposition “left before treatment” and classified with a white criticality code.	[24]
Length of stay compliance	Percentage of arrivals with a length of stay within 8 hours (excluding patients admitted in observation). A value of 100% implies a fully compliance of the standard time fixed by regulations.	[24]
Response time compliance	It enables to monitor the compliance and effectiveness of response according to the priority code assigned: • Percentage arrivals with yellow code examined within 15 minutes; • Percentage arrivals with blue code examined within 60 minutes; • Percentage arrivals with green code examined within 120 minutes; • Percentage arrivals with white code examined within 240 minutes. A value of 100% implies a fully compliance of the standard time fixed by regulations.	[22], [24]

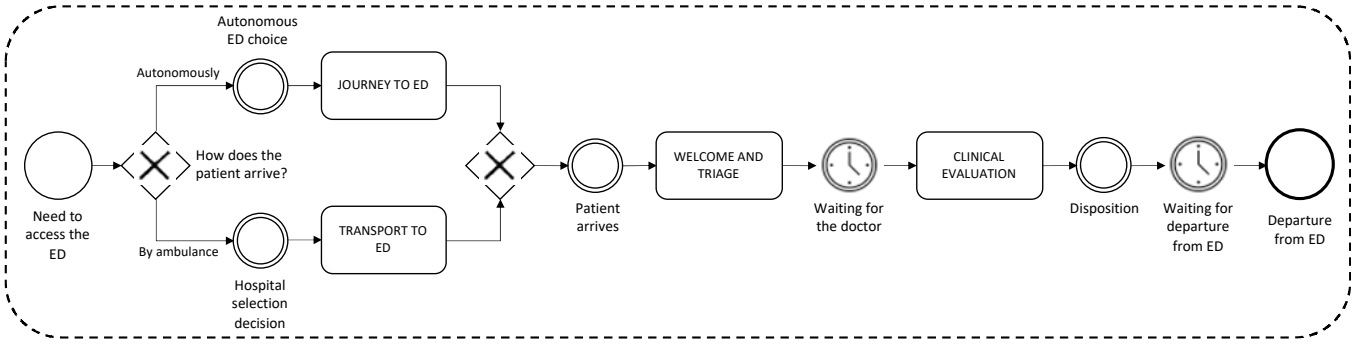

Fig. 3 EMS process considered

2. Exclusion of KPIs that are similar to each other and/or redundant because they are useful for the same purpose. To this end, the indicators have been classified according to their functionality (effectiveness or efficiency) and have been associated with one or more phases of the EMS process. This made it possible to identify the indicators useful for the same functionality and at the same phase of the process, to eliminate redundant and/or similar ones:
a. Among the patients flow metrics: *ED census*, *Left without being seen*, *Medical fit for discharge*, *Unallocated patients with decision to admit*.
b. Among the time interval metrics: *Length of stay*, *Length of stay index*, *Time to nursing assessment*, *Arrival to treatment space*, *Door to doctor*, *Treatment space to provider*.
c. Among the resource metrics: *Physician hours*, *Nursing hours*, *Number of beds*, *Stretcher occupancy*.
d. Among the quality metrics: *Unplanned re-attendances*, *Position index*, *Performance index*.
3. Exclusion of KPIs that cannot be calculated due to the unavailability of data. The dashboard test was carried out on data from the EUOL dataset of Lombardy Region, Italy. It was decided to take as a reference the data for 2019, 2020 and 2021 relating to the territories of Milan and Monza-Brianza which include a catchment area of about 4 million citizens. In this way, it was possible to compare the metrics in a "standard" situation (i.e., a pre-COVID-19 situation), in a highly critical situation (the beginning of the COVID-19 emergency) and in a situation of gradual restoration of the original conditions (context of coexistence with COVID-19). This phase led to the exclusion of the following KPIs:

a. Among the patients flow metrics: *Inpatients rate*.
b. Among the time interval metrics: *Travel time*, *Time to triage*.
c. Among the resource metrics: *Patient-Doctor ratio*, *Patient-Nurse ratio*.

Following this process, it was possible to select the 22 KPIs included in the final dashboard, which was then discussed and evaluated by experts in the field. Table VIII shows the indicators grouped by use and Fig. 5 associates them with the phases of the EMS process.

TABLE VIII
FINAL INDICATORS GROUPED BY USE

KPI	Use
Patients waiting for clinical evaluation	Operational, planning, early warning, information to citizens
ED acuity	Operational, planning
ED case mix by problem	Operational, planning, early warning
ED case mix by diagnosis	Operational, planning, early warning
ED case mix by mode	Operational, planning
Left before treatment completion	Planning
Admission rate	Operational, planning, early warning
Transfer rate	Operational, planning
Crowdedness index	Operational, planning, early warning, information to citizens
Patient flow index	Operational, planning, early warning, information to citizens
NEDOCS	Operational, planning, early warning, information to citizens
Load-off time	Planning
Triage to provider	Planning, information to citizens
Provider to disposition	Planning
Disposition to departure	Planning, early warning
Provider to departure	Planning
Net Patient Throughput Time	Operational
Gross Patient Throughput Time	Operational
Data consistency index	Planning
Length of stay compliance	Planning, early warning
Response time compliance	Planning, early warning
Triage code appropriateness	Planning

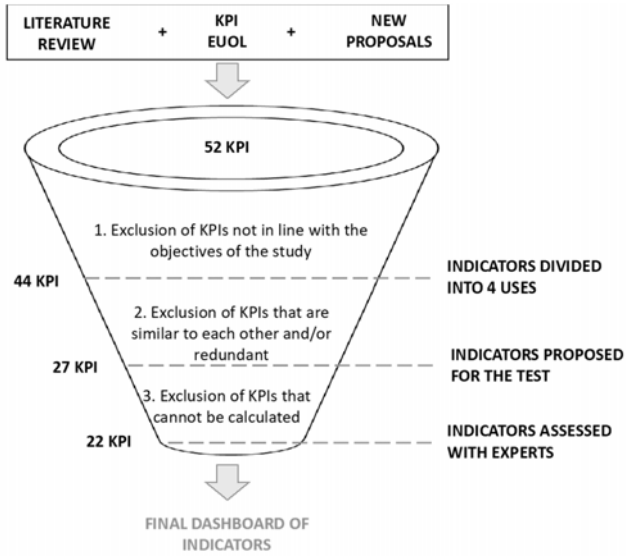

Fig. 4 KPI selection logic

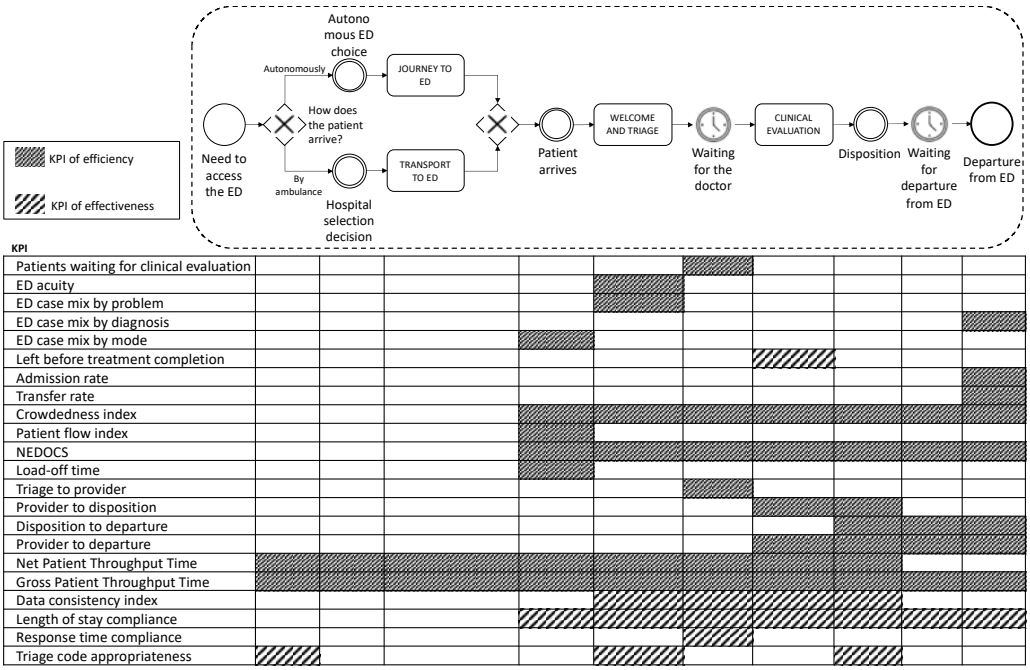

Fig. 5 Association of each KPI to the phases of the EUS process

V. DISCUSSION

A critical review of the insights collected from the test application of the KPIs to a realistic dataset confirmed ability of the proposed dashboard to provide operational, planning, early warning and information support. In particular:

- Operational level indicators allow to analyze the input mix of an ED to better manage the available resources. Furthermore, they permit to investigate the entity of the queues in entry (in the phase before the clinical evaluation in ED) and in exit (in the phase before the departure from the ED). Specific indicators such as the NEDOCS allow to know the situation of overcrowding of the ED. Finally, calculating the Patient Throughput Time can support decision makers in selecting the ED to which the patient will be transported by ambulance.
- Planning level indicators allow to know in detail how the resources are consumed. Indeed, analyzing in detail the mix and the timing of stay permits to know the phases in which the greatest vulnerabilities are encountered. For example, from the tested dataset it emerged that the time components characterized by a higher value and a greater vulnerability are those related to the final phase of the ED process, specifically from the start of the clinical evaluation to the departure from the ED. Furthermore, through this type of indicators it is possible to measure the level of quality and effectiveness of the service provided.
- Early warning indicators were found to be able to detect phenomena of high influx of people and to classify the motivation. They can derive from epidemiological phenomena (such as the case of COVID-19) or other types of phenomena thanks to the analysis of the problem and diagnosis. Furthermore, they allow to detect if the emergency situation impacts on the initial or final phases of the process.
- Information to citizens indicators, lastly, allow the citizen to be informed about the situations of crowding at the entrance of each ED, the number of people and the waiting times. This facilitates the autonomous access of citizens to EMS.

In the proposed final dashboard, each of the four uses is covered by multiple indicators (Table VIII). Therefore, the developed dashboard is complete from this point of view and able to respond in multiple ways to the purposes for which it was created. Furthermore, as can be seen from Fig. 5, the proposed dashboard is able to cover all phases of the EMS process, whether the effectiveness or efficiency of the services provided is measured. However, the initial phases related to the interconnection between ED and ambulance service remain slightly uncovered, for which there is a reduced number of indicators compared to the subsequent ED phases. Moreover, it should be taken into consideration that it was not possible to include the Travel Time as an indicator in the final dashboard, as it is not present in the EUOL dataset of the Lombardy Region used for the KPIs test. This strongly impacts the completeness of the dashboard as it is a fundamental data for measuring the interconnection between ED and ambulance service, in particular for calculating the Patient Throughput Time. This highlights the need to develop a joint dataset between the ambulance service and the EDs of the territory containing more information useful for measuring the interconnection between the EMS services.

VI. Conclusions

In this study we conducted an in-depth literature review of the KPIs to measure the performance of EMS systems, whether they concern the ambulance service side or the hospital service side in ED. The gaps in the literature were highlighted. They mainly concern a lack of indicators able to measure the interconnection between the two phases of the service. Consequently, the study continued with the development of new indicators, designed to fill the gaps observed in the extant literature. Starting from all the reviewed KPIs, through a systematic exclusion/inclusion analysis, it was possible to define a coherent and robust dashboard that allows the analysis of performance at different levels (operational, planning, early warning, and information to the citizen) and for each phase of the EMS process. Finally, the dashboard was validated by experts, and by its application to a realistic dataset (Lombardy Region EMS, Italy).

Given the presence of multiple indicators for each purpose and process phase, the development of a hierarchical framework is suggested for possible future research. It could be composed of a high-level including a subgroup of KPIs sufficient to measure the most relevant performances and subsequent levels obtained by adding additional KPIs among those selected to the basic dashboard. In this way, a dashboard of indicators could be defined to measure the performance of EMS with different levels of detail.

Finally, the need to develop a joint dataset containing more information, useful for measuring the interconnection between EMS processes is highlighted. It is therefore advisable to introduce additional indicators to support the early stages of the process relating to the conclusion of the journey by ambulance. In fact, measuring the performance of the process from the beginning of the ambulance journey until leaving the ED would allow to consider the entire experience of the patient and not exclusively from the moment of its access in ED.

References

[1] El Sayed, Mazen J. 2012. “Measuring Quality in Emergency Medical Services: A Review of Clinical Performance Indicators.” *Emergency Medicine International* 2012: 1–7.

[2] Rahman, Nik Hisamuddin, Hideharu Tanaka, Sang Do Shin, Yih Yng Ng, Thammapad Piyasuwankul, Chih Hao Lin, and Marcus Eng Hock Ong. 2015. “Emergency Medical Services Key Performance Measurement in Asian Cities.” *International Journal of Emergency Medicine* 8 (1): 4–9.

[3] Krafft, Thomas, Luis García Castrillo-Riesgo, Steve Edwards, Matthias Fischer, Jerry Overton, Iain Robertson-Steel, and Anke König. 2003. “European Emergency Data Project (EED Project): EMS Data-Based Health Surveillance System.” *European Journal of Public Health* 13 (3 SUPPL.): 85–90.

[4] Ministero della Salute. 2019. “Linee Di Indirizzo Nazionali Sul Triage Intraospedaliero,” no. 2: 1–135.

[5] Almasi, Sohrab, Reza Rabiei, Hamid Moghaddasi, and Mojtaba Vahidi-Asl. 2021. “Emergency Department Quality Dashboard; a Systematic Review of Performance Indicators, Functionalities, and Challenges.” *Archives of Academic Emergency Medicine*.

[6] Wiler, Jennifer L., Shari Welch, Jesse Pines, Jeremiah Schuur, Nick Jouriles, and Suzanne Stone-Griffith. 2015. “Emergency Department Performance Measures Updates: Proceedings of the 2014 Emergency Department Benchmarking Alliance Consensus Summit.” *Academic Emergency Medicine* 22 (5): 542–53.

[7] Khalifa, Mohamed, and Ibrahim Zabani. 2016. “Developing Emergency Room Key Performance Indicators: What to Measure and Why Should

We Measure It?" *Studies in Health Technology and Informatics* 226 (October 2017): 179–82.

[8] Núñez, Alicia, Liliana Neriz, Ricardo Mateo, Francisco Ramis, and Arkalgud Ramaprasad. 2018. "Emergency Departments Key Performance Indicators: A Unified Framework and Its Practice." *International Journal of Health Planning and Management* 33 (4): 915–33.

[9] Ospina, Maria B., Kenneth Bond, Michael Schull, Grant Innes, Sandra Blitz, and Brian H. Rowe. 2007. "Key Indicators of Overcrowding in Canadian Emergency Departments: A Delphi Study." *Canadian Journal of Emergency Medicine* 9 (5): 339–46.

[10] Abo-Hamad, Waleed, and Amr Arisha. 2013. "Simulation-Based Framework to Improve Patient Experience in an Emergency Department." *European Journal of Operational Research* 224 (1): 154–66.

[11] Kadri, Farid, Sondès Chaabane, and Christian Tahon. 2016. "Reactive Control System to Manage Strain Situations in Emergency Departments." *ICINCO 2016 - Proceedings of the 13th International Conference on Informatics in Control, Automation and Robotics* 2 (January): 576–83.

[12] Castanheira-Pinto, Alexandre, Bruno S. Gonçalves, Rui M. Lima, and José Dinis-Carvalho. 2021. "Modeling, Assessment and Design of an Emergency Department of a Public Hospital through Discrete-Event Simulation." *Applied Sciences (Switzerland)* 11 (2): 1–25.

[13] Duarte, Diego, Chris Walshaw, and Nadarajah Ramesh. 2021. "A Comparison of Time-Series Predictions for Healthcare Emergency Department Indicators and the Impact of COVID-19." *Applied Sciences (Switzerland)*.

[14] Welch, Shari, James Augustine, Carlos A. Camargo, and Charles Reese. 2006. "Emergency Department Performance Measures and Benchmarking Summit." *Academic Emergency Medicine* 13 (10): 1074–80.

[15] Di Somma, Salvatore, Lorenzo Paladino, Louella Vaughan, Irene Lalle, Laura Magrini, and Massimo Magnanti. 2015. "Overcrowding in Emergency Department: An International Issue." *Internal and Emergency Medicine* 10 (2): 171–75.

[16] Postma, Jeroen, and Teun Zuiderent-Jerak. 2017. "Beyond Volume Indicators and Centralization: Toward a Broad Perspective on Policy for Improving Quality of Emergency Care." *Annals of Emergency Medicine* 69 (6): 689-697.e1.

[17] Stefanini, Alessandro, Davide Aloini, Elisabetta Benevento, Riccardo Dulmin, and Valeria Mininno. 2018. "Performance Analysis in Emergency Departments: A Data-Driven Approach." *Measuring Business Excellence* 22 (2): 130–45.

[18] Ismail, Khaled, Waleed Abo-Hamad, and Amr Arisha. 2010. "Integrating Balanced Scorecard and Simulation Modeling to Improve Emergency Department Performance in Irish Hospitals." *Proceedings - Winter Simulation Conference* 2007 (Hse 2007): 2340–51.

[19] Vittadini, Giorgio, Paolo Berta, Michele Castelli, Gianmaria Martini, Luca Giuseppe Merlino, and Carlo Zocchetti. 2012. "Manuale Del Sistema Di Valutazione Della Performance Degli Ospedali Lombardi."

[20] Lin, Chih Hao, Chung Yao Kao, and Chong Ye Huang. 2015. "Managing Emergency Department Overcrowding via Ambulance Diversion: A Discrete Event Simulation Model." *Journal of the Formosan Medical Association* 114 (1): 64–71.

[21] Schull, Michael J., Astrid Guttmann, Chad A. Leaver, Marian Vermeulen, Caroline M. Hatcher, Brian H. Rowe, Merrick Zwarenstein, and Geoffrey M. Anderson. 2011. "Prioritizing Performance Measurement for Emergency Department Care: Consensus on Evidencebased Quality of Care Indicators." *Canadian Journal of Emergency Medicine*.

[22] Di Bella, Enrico, Luca Gandullia, Lucia Leporatti, Marcello Montefiori, and Patrizia Orcamo. 2018. "Ranking and Prioritization of Emergency Departments Based on Multi-Indicator Systems." *Social Indicators Research*.

[23] Tregunno, Deborah, G. Ross Baker, Jan Barnsley, and Michael Murray. 2004. "Competing Values of Emergency Department Performance: Balancing Multiple Stakeholder Perspectives." *Health Services Research* 39 (4 I): 771–92.

[24] ACSS Regione Lombardia. 2020. "Analisi Finalizzate Alla Valutazione Delle Performance Di Pronto Soccorso - Area Di Azione L.R. 33/2009 s.m.i. Art.11 c.4 Lett. d) e G)," 7/8.

[25] Ministero della Salute. 2020. "Specifiche Funzionali Dei Tracciati 118 e Pronto Soccorso."

[26] Emergency Urgency OnLine (EUOL). https://www.astir.com/soluzioni/euol-emergenza-urgenza-online/