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Original article

Cost analysis of emergency department

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Key words

Emergency department • Standard cost • Health care

Summary

This paper is intended to examine both clinical and economic data concerning the activity of an emergency department of an Italian primary Hospital. Real data referring to arrivals, waiting times, service times, severity (according to triage classification) of patients' condition collected along the whole 2009 are matched up with the relevant accounting and economic information concerning the costs faced. A new methodological approach is implemented in order to identify a "standard production cost" and its variability. We believe that this kind of analysis well fits the federalizing process that Italy is experiencing. In fact the federal reform is driving our Country toward a decentralized provision and funding of local public services. The health care services are "fundamental" under the provisions of the law that in turn implies that a standard cost has to be defined for its funding. The standard cost (as it is defined by the law) relies on the concepts of appropriateness and efficiency in the production of the health care service, assuming a standard quality level as target. The identification and measurement of health care costs is therefore a crucial task propaedeutic to health services economic evaluation. Various guidelines with different amount of details have been set up for costing methods which, however, are defined in simplified frameworks and using fictious data. This study is a first attempt to proceed in the direction of a precise definition of the costs inherent to the emergency department activity.

1. Introduction

The standard cost (as it is defined by the law 42/2009) relies on the concepts of appropriateness and efficiency in the production of health care services, given a standard quality level. The control measurement of health care costs is a crucial task in the health economic evaluation even if it is expected that the system of standard costs will *de facto* converge to the average evaluation of resource consumption. Various guidelines with different amount of details have been set up for costing methods in economic evaluation.

Emergency Departments (EDs) pose traditionally a crucial issue concerning hospitals' cost containment and management [1]. In the current scenario of reduced resources to fund public health care providers, hospitals are forced to closely scrutinize information of their EDs with particular reference to their cost. Hospital EDs are considered by part of the literature [1, 2] as a potential source of cost inefficiency within the national health system. However, despite the importance of the EDs in terms of resource consumption both for the national health care system and single hospital budget, very little is known and studied about their cost structure.

As a consequence of the increase in the cost for the national health system and of the local government deficit, the EDs must, along with the other departments and the whole health care system, pursue the cost containment goal in such a way that the overall quality and the level of services provided would not decrease. Therefore it turns to be crucial to define indexes and criterions to evaluate the EDs in terms of efficiency and quality [3-5].

This paper is intended to move in the direction of the analysis of ED cost composition and impact by a investigation based on microdata referring to the health related services provided by a ED belonging to an Italian primary Regional Hospital. The data collected refer to the year 2009 and count for 53,021 patients which have been assisted during the whole 2009 by the ED of Ospedali Galliera, one of the most important hospitals in the City of Genoa. For each patient the variables available refer to arrivals, waiting times, service times, severity of the patients' conditions (according to the triage classification), number and typologies of services offered, gender, age, domicile and nationality.

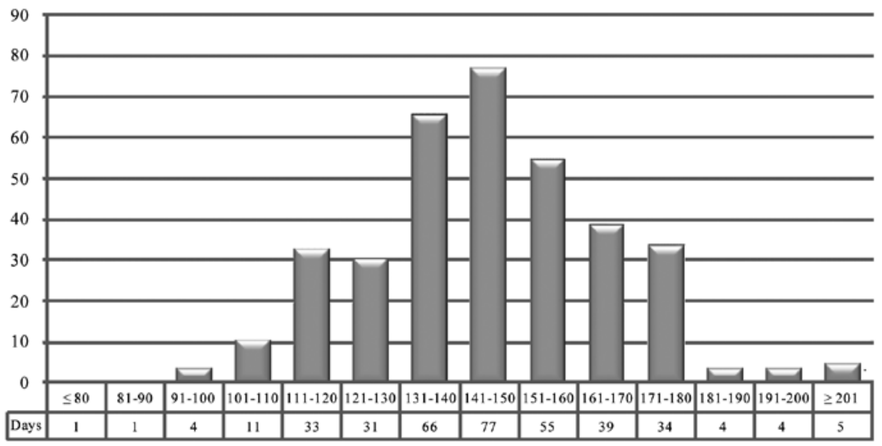
The clinical data are matched up with the relevant accounting and economic information concerning the cost faced by the ED.

Our goal consists in providing a new approach in order to identify the standard production costs and their variability between the different types of patients.

The paper is organized as follows: section 2 provides a descriptive analysis of the most important clinical data referring to the ED activity. Subsequent section 3 focuses on cost definition by matching clinical and economic data. Concluding remarks are reported in section 4.

2. Waiting times, overcrowding and patients' triage coding

Fig. 1. Frequencies of patients (by classes) turning to the ED in year 2009.



In this work, patients' cost will be decomposed with respect to a number of measures the most relevant of which is the triage coding color [6-8]. In order to understand the composition of the patients which the ED assisted during the whole 2009, a deep descriptive analysis is herein proposed in order to understand how much the traditional structural differences among patients affect the cost of their assistance and the performance of the ED as a complex structure. A particular focus will be centered on yellow triage codes which are the typical benchmark used by EDs to check their performance.

Figure 1 provides the arrivals distribution measuring the number of days in which the number of patients arrived at the ED was in the class intervals whose boundaries are the minimum and the maximum number of patients per day specified. For instance the class 141-150 includes all the days of the year in which the number of patients that turned to the ED were comprised within a minimum value of 141 per day and a maximum value of 150 per day. This condition was verified 77 times (i.e. 77 days) in the 2009 year time. The classes which highlight the largest frequency are those encompassed between 131 and 160 patients per day: they represent the 54% of the days of the year. Looking at the range 101-190 we are able to represent almost the 92% of all the days of the year.

Starting from some preliminary considerations can be done with reference to the average patient flow at the ED and indirectly to the effects of overcrowding on the quality of the services provided. With some approximation we may assume as proxy of health services' quality the variability of waiting time. The "crowd" increases with the number of patients that make use of the ED in a single day. If we assume that the "standard range" is represented by the interval 131-160, then overcrowding is detectable any time the limit of 160 patients per day has overcome, i.e. in the 23,56% of the days of the year. Although the daily flow of patients is not the sole component of overcrowding, nonetheless it is a key determinant which may be intended to be a good first approximation of ED stress.

What it is important to test is the hospital reactivity to this stress, mainly in terms of waiting times for all the triage color patients. It is clear that for an ED the waiting

Tab. I. Descriptive statistics of patients per class interval.

Class interval (patients per day)	Number of days	Total number of Patients	Ages		Outcome			
					Discharged		Hospitalized	
			Average	Median	Patients	% Total	Patients	% Total
81-90	1	87	55.51	25	63	72.41%	22	25.29%
91-100	4	390	50.62	46	292	74.87%	80	20.51%
101-110	11	1,158	49.35	45	905	78.15%	224	19.34%
111-120	33	3,820	50.43	47	2,933	76.78%	750	19.63%
121-130	31	3,882	49.44	46	3,075	79.21%	647	16.67%
131-140	66	8,969	50.18	46	6,898	76.91%	1,687	18.81%
141-150	77	11,264	49.68	46	8,712	77.34%	2,050	18.20%
151-160	55	8,532	49.53	46	6,727	78.84%	1,460	17.11%
161-170	39	6,435	49.78	46	5,088	79.07%	1,056	16.41%
171-180	34	5,939	49.33	46	4,687	78.92%	971	16.35%
181-190	4	739	49.19	45	588	79.57%	119	16.10%
191-200	4	780	48.97	46	597	76.54%	136	17.44%
> 200	5	1,024	49.38	46	829	80.96%	152	14.84%

time is crucial given the peculiarities of its medical activity. As a consequence, on the basis of the relation between the waiting time and the number of patients it is possible to evaluate the department behavior and its efficiency.

Our investigation starts by looking at the composition in percentage of patients according to their triage code (Fig. 2).

A relevant variation in the percentage composition of codes for each class does not seem to emerge. In other words we may state that the increase in the patients flow is "proportional" among the different types of patients. Looking at data in Table I, which provides information concerning the mean and median age per ED level of activity, it can be stated that no symptomatic differences in age group means and medians emerge. The same conclusion is grasped from the study of the outcome ("discharge" or "hospitalization").

Table II below refers to the clinical pathway of patients in terms of waiting time. Two different time are considered: the time of the first examination and the closing time of the patient report. To be noted that the lapse is expressed in decimal units rather than standard units.

Data are clustered according to the classes as previously defined. The column "*All Patients*" sums up all the different triage codes inside that patient class. For instance, inside the class 101-110 the average waiting time (for all patients) is 31,32 minutes (0,522 h × 60 minutes = 31,32 conventional minutes), whereas the class 181-190 shows an average waiting time equal to 58,92 minutes (0,982 × 60 = 58,92 conventional minutes).

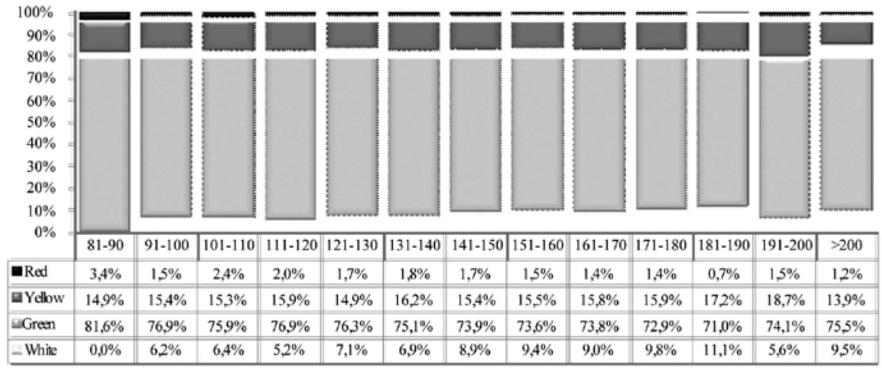


Fig. 2. Volume activity by classes (patients per day).

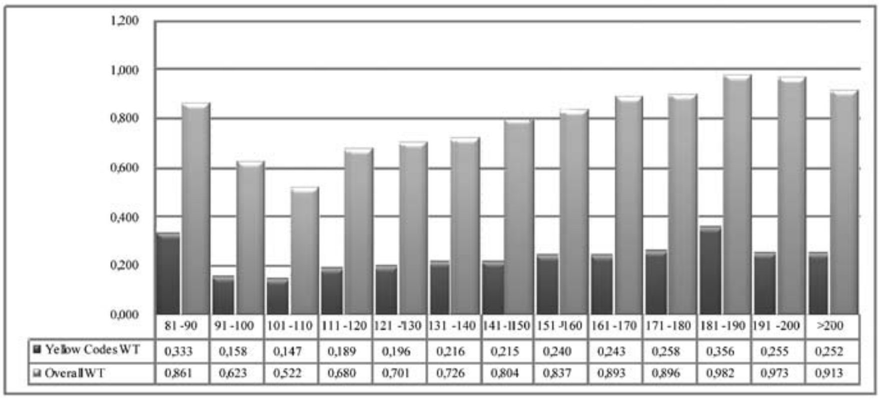


Fig. 3. Average waiting times (WT) per ED activity for all the codes and yellow codes only.

Tab. II. Waiting times for arrival intensity classes.

Class interval (patients per day)	Waiting Time Triaging – 1st examination				Waiting Time Triaging – Patient's Report Closing			
	All Patients		Yellow Codes		All Patients		Yellow Codes	
	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
81-90	0.861	0.881	0.333	0.503	2.896	2.932	4.381	3.922
91-100	0.623	0.686	0.158	0.203	2.572	3.546	3.996	4.989
101-110	0.522	0.624	0.147	0.119	2.471	3.401	3.861	4.886
111-120	0.680	0.788	0.189	0.195	2.667	3.645	4.459	5.708
121-130	0.701	0.808	0.196	0.242	2.708	3.537	4.408	5.420
131-140	0.726	0.836	0.216	0.274	2.721	3.350	4.073	4.908
141-150	0.804	0.917	0.215	0.259	2.770	3.343	4.149	5.097
151-160	0.837	0.903	0.240	0.311	2.796	3.305	4.158	5.055
161-170	0.893	0.944	0.243	0.342	2.865	3.321	4.285	5.157
171-180	0.896	0.983	0.258	0.381	2.826	3.197	4.040	4.808
181-190	0.982	1.038	0.356	0.499	2.964	2.984	4.109	4.296
191-200	0.973	1.168	0.255	0.286	2.964	2.984	4.142	4.575
> 200	0.913	0.967	0.252	0.315	2.742	3.002	3.849	4.345

The classes that present the lowest standard deviation are those between 91 and 121 patients. The higher the standard deviation is, the higher is the expected variance around the mean.
Figure 3 synthesizes data referring to average waiting times. It turns out that the optimal volume activity with reference to the ED is the interval 101-110. However a good response of the ED is detectable even in the interval 91-130, in which the average waiting time with reference to the yellow codes fall below 12 minutes for the first examination. The waiting time peak is within the class 181-190 in which the value of 0,356 is reached (equal to 21,4 minutes, about twice the time of the class 101-110). The average waiting time for high volumes of ED activity (more than 191 patients) decreases as a result of the integration of the medical staff by the director himself of the ED and other doctors. Figure 4 refers to the standard deviation. By this index it is possible to compare the different classes. The lower the standard deviation is the lower is the dispersion around the mean of observations, and as a consequence more likely is that the waiting time of the patient coincide with the average one.
From the visual inspection of Figure 4 emerges quite clearly the relationship between the variability in waiting times (measured through the use of the standard deviation) and the ED crowding (measured through the patients daily flow). The information is also provided with reference to yellow codes only (that are generally considered a more reliable dataset as white and green codes are often subject to the presence of censuring, outliers and measurement errors). Summing up, it doesn't seem that the volume of patients affects the ED activity, or equivalently that a overcrowding effect is detectable. This is supported also by the low correlations between the Triaging – 1st examination times for all the codes and yellow codes only (Tab. III) and the number of patients assisted in the day. These correlations are both very low and the fact that latter is higher than the former confirms a lower impact of overcrowding on yellow codes waiting times. The average waiting times per activity level is furthermore investigated through the graphic representation of Figure 5. The size of the bubbles in plot is proportional to the number of days is which the number of patients indicated in the horizontal axis has been reached.

Fig. 4. Standard Deviations (SD) waiting times (WT) per ED activity for all the codes and yellow codes only.

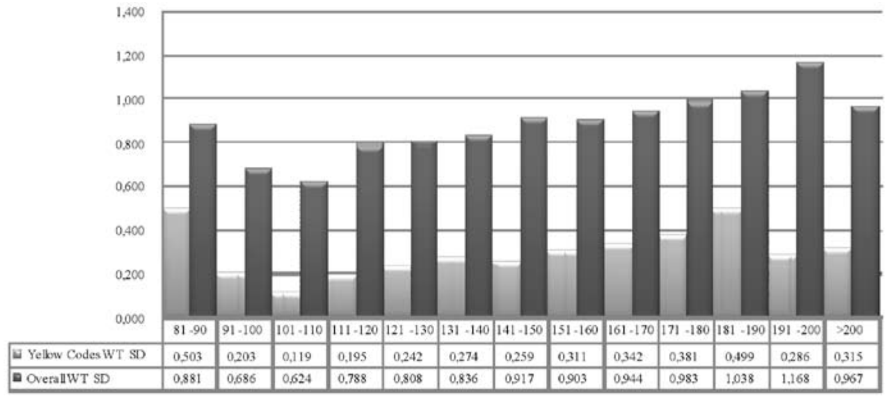
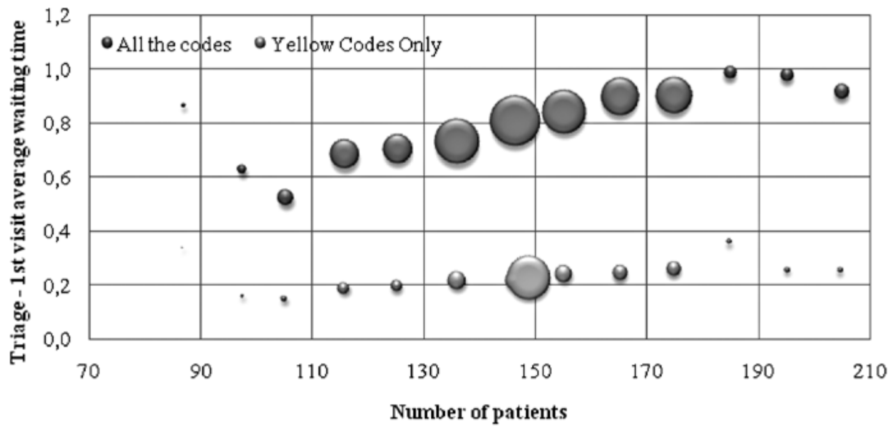


Fig. 5. Mean Triage-1st visit waiting times per different levels of activities.



Tab. III. Pearson's correlations vector for the number of patients in the ED and some relevant variables.

	Correlation with Number of patients per day
Triaging – 1st examination waiting times	0.09
Triaging – 1st examination waiting times (Yellow codes only)	0.08

3. The ED's costs

The ED faces a number of different costs that can be classified as fixed, variable and common*. Fixed costs are those costs that do not vary on the number of patients treated. Because of the labor market rigidity (at least with reference to the Italian case), the cost for workers has been computed within the fixed costs. The main component of fixed costs relies on medical and non-medical staff (which represents the 90% of fixed costs and the 70% of total costs). On the other hand variable costs count just for a 6% of the total. The common costs

* The percentage composition of these costs is provided in Table IV.

Tab. IV. Cost composition and detail for Ospedali Galliera ED.

Cost Composition		Fixed Costs Composition		Variable Costs	
Fixed Costs (FC)	78%	Medical Doctors	39%	Surgical & Medical devices	48%
Common Costs (CC)	16%	Nurses	34%	Drugs	23%
Variable Costs (VC)	6%	Other Personnel	16%	Kitchen & Laundry	21%
Total	**100%**	Mortgages and other expenses	9%	Health Services	8%
		Administrative Staff	1%	**Total**	**100%**
		Cleaning	1%		
		Total	100%		

Tabl. V. Patients composition per outcome and severity level.

Triage Code	Discharge	Short Hospitalization	Hospitalization	Observation	Total	% out of total
White	3,910 89.35%	4 0.09%	116 2.65%	346 7.91%	4,376 100%	8.30%
Green	33,484 85.22%	866 2.20%	3,398 8.65%	1,543 3.93%	39,291 100%	74.50%
Yellow	3,954 48.07%	754 9.17%	3,410 41.45%	108 1.31%	8,226 100%	15.60%
Red	47 5.51%	67 7.85%	739 86.64%	0 0%	853 100%	1.60%
Totals	41,395 78.48%	1,691 3.20%	7,663 14.53%	1,997 3.79%	52,746 100%	100%

refer to activities not directly attributable to the structure but nonetheless useful to its functioning (for instance the cost for a competitive examination required to hiring a new specialist or the cost inherent to a new contract procedure or to invite bids).

At first it is possible to match the cost related data with information regarding the number of patients in order to identify the per patient cost. The latter turns out to be equal to 129.28€ and it is constituted as follows:

$$\frac{FC + VC + CC}{N.\,of\ Patients} = 129.28€ = \begin{cases} 100.24\ (fixed\ cost) \\ 8.30\ (variable\ cost) \\ 20.77\ (common\ cost) \end{cases} \quad (1)$$

However, using the data at our disposal, a new scenario for the cost structure can be depicted. In Table V patients are grouped according both to outcome and triage classification.

With reference to year 2009, the white codes represent the 8,3% of the total accessions to the hospital's ED whereas the green are the 74,5%, the yellow the 15,6% and the red the 1,6%.

Both for white and green codes the outcome "discharged" represents the most likely (respectively the 89,35% and the 85,22%) and hospitalization is the most likely outcome for yellow and green patients (respectively 50,62% and 94,49%). It clearly emerges that the red codes will be, almost for sure, hospitalized. However this latter represents only the 1,6% of the total amount of patients admitted to the ED.

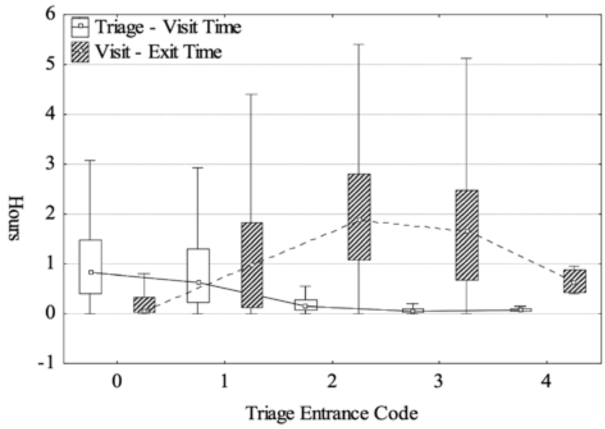
Exploiting these data we can compute the total cost per patient according to the structure as it is shown in Table VI. As we would expect, Observation and Short Hospitalization show a cost per patient which is nearly three times and a half the cost per patient of the ED only. Furthermore by considering that even hospitalized and in observation patients "pass through" the ED structure, it clearly emerges that the per patient ED cost are overestimated.

It deserve to be noted that fixed and common costs represents 94,25% and 87,6% of total cost respectively for

Tab. VI. Per patient (structure) cost.

Structure	Cost per patient
Emergency Department	€ 126.69
Observation and Short Hospitalization	€ 426.96

Fig. 6. Box plots (min, 25th, 50th, 75th centiles and max) of the waiting times distributions for the Triage – 1st visit and 1st visit – patient's exit time (0: White codes, 1: Green codes, 2: Yellow codes, 3: Red Codes, 4: Black codes - dead at ED arrival).



Tab. VII. Triage codes weights, patients and equivalent patients.

Triage Code	White	Green	Yellow	Red
$Weight_{TriageCode}$	1	1,5	2	2,5

the Emergency Department and Observation and Short Hospitalization.

However costs should be imputed according to the actual resource consumption that is generally strictly correlated with the patient severity. To this extent we use the triage classification code as proxy for the patient's severity, which is in turn directly correlated with the actual cost. The hint underlying this statement can be empirically grasped looking at Figure 6 in which is presented the box-plot of waiting times elapsing from "Triage – 1st Visit" and "1st Visit – Patient's Exit".

The time elapsing to receive the first visit (after the triage attribution) decreases along with the patient severity (i.e., the triage code). On the other hand the time elapsing between the first examination and the exit time increases in the triage classification. To this extent we assume that a larger time period to exit implies a larger resource consumption by patient in terms of: i) medical and non-medical staff; ii) clinical tests; iii) drugs; iv) equipment; v) other. In order to take into account this information we have arbitrarily weighted the patients according to their triage color (consistently with the Italian "*progetto mattoni*" which provides for a weight depending on the triage color).

As it clearly emerges from Table VII the *white code patient* turns to be a sort of benchmarking for the weight associated to other colors. For instance a green code is assumed to have a cost 50% greater than a white. A yellow code costs twice the white. Finally the red code is equivalent to two times and a half the white code. In other terms we may think at equivalent patients, where the "equivalence" refers to cost. The hospitalization of a yellow code patient is equivalent, in terms of resource absorption, to two white code patients. This new scenario suggests a new cost classification which takes into account the triage classification. Two hypothesis are possible:

$$_{structure}PatientCost_{TriageCode} = \frac{FC + CC}{N.of\ Pat.} + \frac{VC}{Eq.Pat.} * Weight_{TriageCode} \quad (2)$$

$$_{structure}PatientCost_{TriageCode} = \frac{FC + CC + VC}{Eq.Pat.} * Weight_{TriageCode} \quad (3)$$

By the first hypothesis (2) the new equivalent patients are used to assess only the variable cost component, while the other cost component stick with the previous setting where patients are not weighted.

The assumption underneath relies on the fact that only variable costs should be affected by the intensity of the clinical assistance whereas fixed costs do not vary.

The second hypothesis (3) moves from the observation that we are searching, from an economic point of view, the actual resource consumption by different types of patients. To this extent all the cost incurred by the ED are shared using the weighted patients criterion.

Table VIII presents the per patient cost that emerge from the two afore-mentioned hypotheses.

It is crucial to carefully consider the patient resource absorption in order to assess his actual cost. We can observe, for instance, that the cost for a white code might vary from a minimum of 84,36 € to a maximum of 407,35 € depending on the cost computation methodology and on the outcome of his clinical pathway.

4. Concluding remarks

One of the most demanding Departments in terms of economic resources consumption and programming is the ED. To this extent its activity should be monitored and optimized in order to provide the best outcome in terms of quality of care subject to a budget constraint. Optimization of patient flow and bottleneck elimination in key departments could be a viable way at policy maker disposal to decrease operational cost and boost the quality of care [5, 9]. The ED is one of the most highly congested units and it faces greater pressure compared with other departments of the health care system. Delays in the ED may have particularly dramatic outcomes for patients. Under these pressures, it is crucial for hospitals to develop a new methodology to improve the patient flow, providing the best possible care in a timely manner, and ensuring optimal utilization of limited resources.

By this paper we have statistically analysed some of the most important aspects inherent the ED activity and matched them up with the related costs. By the hypothesis we have set in the paper, it emerges a great variability in the per patient cost depending on the outcome, the patient severity and the health treatment structure. This paper is a "first step" propaedeutic to further investigation with reference to the ED cost identification and classification. A clear and neat cost definition is the necessary tool that may allow the implementation of a prospective reimbursement scheme, based on tariffs, also with reference the ED activity. As the economic literature has shown, a prospective payment (for instance based on standard cost) would be the most effective incentive to induce efficiency in health care provision.

Tab. VIII. Total costs per triage color, structure and hypothesis.

	Hypothesis 1		Hypothesis 2	
	Emergency Department	Observation and Short Hospitalization	Emergency Department	Observation and Short Hospitalization
Cost per Equivalent Patient	€ 124.25	€ 407.35	€ 84.36	€ 268.94

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