

MODELLING THE COSTS OF PRE-HOSPITAL TRANSPORT SERVICE FOR VICTIMS OF ROAD ACCIDENTS IN TDABC

Abdelaziz ZERKA¹, Fouad JAWAB²

^{1,2} Industrial Technologies and Services - High School of Technology, Sidi Mohamed Ben Abdellah University, Fez, Morocco

Abstract:

The pre-hospital transport of victims of road accidents in Morocco by basic ambulances concerns the majority of the population of victims requiring urgent care. It also constitutes the common service that benefits the entire population of victims, in terms of pre-hospital care. The objective of this contribution is to develop a model for calculating the costs of pre-hospital transport of road accident victims using Time-Driven Activity-Based Costing (TDABC). This model could be effective in better understanding how consumption occurs and how resources are administered and distributed within the pre-hospital care service portfolio. The qualitative research approach that we have adopted in the context of this study has enabled us to map and identify all the activities and tasks carried out in the process of pre-hospital transport of road accident victims. The model obtained is flexible enough to adapt to the various situations of pre-hospital transport of road accident victims by basic ambulances. The application of this model in the Moroccan context, delimited in a well-defined round trip (civil protection - accident site - hospital - civil protection) demonstrates that the said model is valid for cost calculation. The calculations made (217.47 MAD, 224.31 MAD, 225.45 MAD and 226.59 MAD) allow us to identify the possible cases of victims transported by basic ambulance. However, the TDABC, applied to the pre-hospital transport of road accident victims, has some limitations, in particular the estimation of time which is the main key to the allocation of the consumed resources. The results show that the TDABC promotes a better knowledge of all the processes related to the pre-hospital transport service. It allows making visible the value of the costs of the victims of road accidents in the selected patient population. Indeed, when the model is used in the set of routes (black points), decision makers are able to see, on the one hand, the variation of costs between similar pre-hospital transport services and different routes for the same transport services and, on the other hand, the value of the costs of each category of road accident victims' population.

Keywords: cost calculation, Morocco, pre-hospital transport, road accident victims, TDABC

To cite this article:

Zerka, A., Jawab, F., (2022). Modelling the costs of pre-hospital transport service for victims of road accidents in TDABC. Archives of Transport, 61(1), 89-101. DOI: <https://doi.org/10.5604/01.3001.0015.8197>



Contact:

1) abdelaziz.zerka@usmba.ac.ma [<https://orcid.org/0000-0003-0703-2083>] - corresponding author;
2) fouad.jawab@usmba.ac.ma [<https://orcid.org/0000-0002-0508-7278>]

1. Introduction

Road traffic injuries are a serious public health problem in Morocco. It requires concerted efforts to both prevent and reduce their impact. The time of the emergency call, the rapid arrival of emergency personnel at the scene of the accident, followed by pre-hospital transport equipped with qualified health care personnel, and the hospital care provided can reduce the consequences of road accidents. However, the entire health care pathway for road traffic accident victims (pre-hospital, hospital and home) constitutes a considerable cost to the economy of many countries. The calculation of the costs of pre-hospital transport of road traffic accident victims, which is the objective of our study, provides information for a better use of resources and helps to understand the way in which consumption is achieved. This calculation provides accurate estimations of the costs of pre-hospital transport for effective and appropriate decision-making.

The cost of pre-hospital transport of motor vehicle accident victims places a significant burden on the already overburdened pre-hospital health care system. There is no doubt that pre-hospital transport facilities around the world, while seeking to meet the needs of an increasingly demanding population (Jawab et al., 2018), are under increasing pressure to reduce costs and better manage their operations. Improving the financial management of these facilities is, however, a great challenge, because they are part of a complex system composed of many devices, including casualties, pre-hospital care providers and support services. These facilities require organizational systems that are capable of efficiently collecting information relevant to decision making. It is therefore essential to further improve the performance of financial management and to define approaches to better manage this complex environment in the economic system subject to high standards of pre-hospital care quality and cost containment (Troyer et al., 2005). This quality of care, in terms of victim and provider satisfaction and compliance with regulatory standards, has become a major concern for prehospital care facilities and can help reduce costs and delays (Frichi et al., 2019).

In addition, cost modelling is needed to accurately measure the actual costs associated with pre-hospital care and create a pricing system. This would help managers to know where they are coming from, and to make decisions to better manage resources and

distribute them within the care service portfolio. This area of research uses costing tools to estimate the value of health care services and benefits by comparing costs and outcomes.

Although the importance of costing pre-hospital care services and its implementation is challenging in practice, given the lack of costing standards, researchers have explored and experimented in recent years with systems that can determine healthcare costs based on activities, such as Time-Driven Activity-Based Costing (TDABC).

Certainly, in Morocco as elsewhere in the world, the pre-hospital care services provided to victims of road accidents, as well as the support services that follow, are numerous, complex and varied depending on the victim's state of health. We have chosen the pre-hospital transport of road accident victims as a model because it:

- Concerns the majority of our population of patients requiring urgent pre-hospital care.
- Constitutes the commonality that the entire population of victims enjoyed in their care journey.
- Also relates to the personnel, equipment and processes used for the pre-hospital transport of victims of road accidents, which are, among other things, similar to those required for other pre-hospital transport procedures for victims of the increasingly frequent disasters and accidents of everyday life (falls, shocks, burns, electrocutions, drownings, poisonings and other accidents).
- There is a real need, as confirmed by the literature (Zerka and Jawab, 2020), to have a tool for controlling the costs of pre-hospital transport.

Our reflection will be articulated as follows: first, we will present the general framework of the analysis; then we will specify the adopted research method; after that we will develop our model of calculation of the costs of pre-hospital transport of victims of road accidents in TDABC; finally we will apply this model on a practical case, namely the Hassan II boulevard, located in Fez- Morocco.

2. General framework of the analysis

2.1. TDABC in health care services

TDABC, which has been successful in several areas including industry and service production (Sophie and Werner, 2010), was introduced by Kaplan and Anderson (Kaplan and Anderson, 2004) as a modified version of ABC. TDABC is a micro-costing

methodology based on a process approach that can optimize costing efficiency and thus overcome a major challenge associated with traditional costing methods. However, previous attempts have attempted to develop analytical, process-oriented compatibility methods in healthcare. We cite here the example of activity-based costing (ABC) introduced by Cooper and Kaplan in the mid-1980s as an alternative to so-called traditional cost accounting methods. We refer, in this respect, to its application in service activities, particularly in hospitals and care services, which has flourished since the early 1990s (Baker, 1998). However, the implementation of this system (ABC) has proven to be difficult, especially since it is too resource intensive in large or complex organizations (Kaplan and Anderson, 2004, 2007). After peaking in the mid-1990s (Udpa, 1996), the subsequent demise of ABC (Tang et al., 2010) illustrates the need to balance the validity of costing with the resources expended to achieve validity (Lipscomb et al., 2009). To overcome these problems, TDABC has been appreciated as a costing tool that seeks to strike this balance and capture business processes accurately. Indeed, it allows for simpler costing models than ABC (Kaplan and Anderson, 2004).

Certainly, today's health care requires the use of new technologies and developed care services that are essential to add value and provide qualified care services. The development of the latter is one of the main drivers of the enormous increase in health care costs (Lamuraud and Lhuillery, 2016). In light of this increase, the TDABC method is being touted as the solution to the health care cost crisis (Kaplan and Porter, 2011). However, this method has been found to be well suited to managing the evaluation of complex health care benefit costs (Au and Rudmik, 2013; Campanale et al., 2014; Demeere et al., 2009; McLaughlin et al., 2014) This allows healthcare organizations to compare their costs to reimbursement rates. In addition, it has also been introduced to healthcare to accurately measure patient care costs, especially since a U.S. study (Kee, 2012) appears to show that TDABC reduces utility cost.

The main advantage of TDABC in health care is its ability to estimate resource utilization for a particular care cycle. The trajectory of care begins, first, with pre-hospital care (during transport), then through hospital care, and finally, this trajectory

may incorporate home care. However, the pre-hospital care service, considered as the beginning of a continuum of care, receives more attention in the care pathway of car accident victims for the modeling of costs in TDABC, because, on the one hand, it is considered an individual, well-defined and comparable care procedure that the method (TDABC) allows (Oklu et al., 2015). On the other hand, the treatment plan for a traffic accident victim with different risk factors may involve several hospital services, almost none of which have a standard and similar treatment plan. Pre-hospital transport was the common care benefit for all victims of motor vehicle accidents requiring medical treatment.

2.2. The measurement of costs by the TDABC method in pre-hospital transport of road accident victims

The TDABC approach allows modeling of the costs of pre-hospital transport of victims of road accidents. This model is intended to provide value to victims. It allows a more complete understanding of the cost of performing procedures and a more accurate measurement of the real costs associated with this type of transport. A specific approach can be developed to address these issues. Ultimately, the goal is to demonstrate to decision makers that the prehospital transport service for motor vehicle accident victims is a cost-conscious phase.

The TDABC approach, applied to the pre-hospital transport of road accident victims, presupposes that the activities have been mapped and the process modelled. In the TDABC approach, two important parameters must be taken into consideration at each step of the process: the estimated cost of each resource used in the process and the practical capacity (time). The main steps in implementing TDABC are as follows (Figure 1).

The mapping of pre-hospital transport activities is essential in the process. We took note of the existing process maps in the health protocol for the care of victims, enriched by interviews with the main actors (ambulance technician, stretcher bearer). The identification of the resources consumed (human and material resources, etc.) at each stage of the process is based on a developed methodology. The estimation of the practical capacity (time) is the determination of the total time spent on the activities of this type of transport. Finally, the time equation is used to model

the costs of the resources consumed for each task in the process.

In fact, we believe that the TDABC approach is the most accurate denominator for estimating the costs of prehospital transport services for certain medical interventions at the disaster site, such as prehospital transport of motor vehicle accident victims.

2.3. The particularities of pre-hospital transport of road accident victims

The population explosion in cities around the world is causing, among other things, traffic congestion. This congestion is considered one of the causes of road insecurity (Moufad and Jawab, 2019). This is especially true since the city, as a space, has a very high transport and traffic dynamic compared to areas outside it (Bebkiewicz et al., 2021).

Morocco is no exception to this reality. As a result, the accident rate has clearly evolved in a context marked by the massive use of cars and other means of transport (Zehmed and Jawab, 2021). Pedestrians, also involved in urban mobility, are highly exposed to traffic accidents (Tafti and Reza, 2021).

Road accidents have several types of adverse effects. Most importantly, they result in loss of life and injury. Accidents are classified by severity: The severity of an accident is defined as the severity of the condition of the victim most seriously injured in the accident. Victims are also ranked in order of severity (death, serious injury, and minor injury). However, the injuries suffered by victims differ from one accident situation to another (fracture, injury, etc.). The steps in the treatment of a medical problem, following a road accident, are pre-hospital, hospital and home and are the source of various costs: ambulance, medical expenses etc.

However, care during transport is a significant cost in the victim's care pathway. This involves various costs: ambulances, personnel, care services, etc. The value of the costs of these elements can be estimated on the basis of the supply costs of this service. Questions arise about the cost of this transport. The pre-hospital care of victims of road accidents in Morocco is provided by ambulances belonging to the civil protection. The state pays for this service. The model of calculation of the costs in TDABC of pre-hospital transport of the victims of the road accidents, objective of our study, allows to:

- Accurately measure the cost of pre-hospital transport as an integral part of the victim's complete care.
- Also measure some of the socio-economic cost value of road accidents.
- Organize pre-hospital transport as needed.
- Know the time and process.
- Control the resources allocated to this activity.
- Give the decision-maker the means to manage the costs of this activity.

It is worth noting that the pre-hospital transport service for victims of road accidents contributes to the medicalized collection of victims, to significantly increase the chances of survival and reduce the risk of lifelong injury, also considered the beginning of a continuum of care that form a "trauma chain" (Coats and Davies, 2002). The ambulance is the means of transporting them to the most appropriate care structure for their case. However, rapid response, effective pre-hospital care, prompt rescue and adequate transport of victims by qualified health care personnel can reduce the severity of injuries and the number of preventable deaths. In Morocco, traffic accidents cause an average of 7300 deaths and 135000 injuries per year. Faced with this situation, the civil protection provides the population 24 hours a day with a single, easy to remember, permanent and free call number "15" to ensure a permanent response to requests for assistance and pre-hospital care.

The pre-hospital transport of victims of road accidents is considered one of the main activities for civil protection, carried out by state-qualified ambulance drivers. The transport of a light casualty (sitting or standing) is the transport of victims, whose state of health does not require medical assistance or supervision, requiring the presence of only an ambulance technician and a stretcher bearer. Lying down or serious injury transport is the transport of victims whose state of health requires, in addition, medical supervision during transport. Their choice depends on the severity of the case, the distance to be covered, the technical means to be used and the difficulties of access to the accident site. In this sense, the types of ambulances, the equipment and the personnel that can intervene for the medical pick-up of road accident victims must be taken into consideration. The Table 1, that we have elaborated, gives two types of ambulance of the civil protection service.

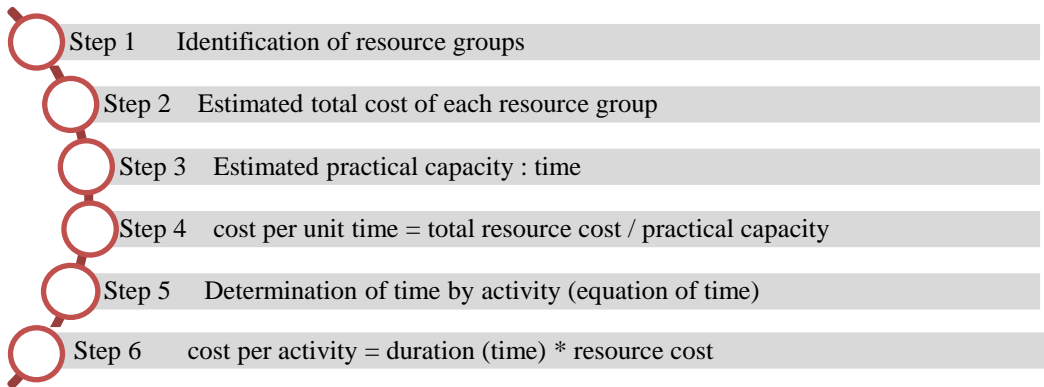


Fig. 1. Main steps in the implementation of TDABC (Everaert et al., 2018)

Table 1. Types of ambulance, equipment and personnel for medical pick-up of traffic accident victims

Ambulance	Ambulance features	Material	Staff
Basic ambulance	Basic ambulance used to transport patients who do not require special care and whose condition is stable.	-Equipped vehicle: - Stretcher - Cart -Splint set of immobilization -source of oxygen	-Technician ambulance driver -Stretcher Bearer
Emergency and resuscitation ambulance	Intensive care ambulance is equipped for transport, intensive care and monitoring. It is equipped with all the medical equipment necessary for resuscitation and intensive care. It transports patients from the public highway to a facility equipped to care for a person in distress whose condition has not been stabilized.	-Highly equipped: -resuscitation equipment -DSA -Scanner -Multiparameter monitor; -Infusion device -Transport ventilator	-Technician ambulance driver -Stretcher Bearer -Physician

3. Research method

From a scoping study of the literature on the subject of pre-hospital transport, we concluded that the standards of pre-hospital care do not allow for an on-site evaluation. Similarly, it is difficult to monitor the pre-hospital transport process of traffic accident victims, to measure the care provided in the ambulance and to record the actual time consumed. Real-time observation is abandoned. Faced with this situation, the approach adopted to test the TDABC in the pre-hospital transport of road accident victims is based on the method of qualitative research, in the field, following an individual interview approach with several providers who perform the tasks of the pre-hospital transport process of road accident victims. The choice of the interview is in line with the work of Alcouffe and Malleret (2002) who considers that the interviews allowed to schematize and identify all the activities and tasks. Similarly, for

Shankar and Anzai (2020), the TDABC relies on the involvement of frontline workers and those who perform the tasks studied.

In general, current costing mechanisms (TDABC) often focus on measuring costs for small units, such as a service or individual procedures. The TDABC method allows prehospital transport of traffic accident victims for each type of ambulance to be taken as a separate activity. In this sense, we chose the Basic ambulance as a case study to model the TDABC cost of pre-hospital transport of road accident victims, as it represents the majority of our victim population, and also the most mobilized for medicalized victim pickup.

Remember that the pre-hospital transport by basic ambulance is the round trip (Civil Protection - accident site - hospital - Civil Protection) of the victim whose health condition is stable, performed by the ambulance technician and stretcher bearer, as well

as pre-hospital care procedures such as oxygenation, splint placement, etc.

It is important to note that the interviews we conducted with the providers of pre-hospital transport of road accident victims by basic ambulance (ambulance technician and stretcher bearer) were based on their practices in order to assess their compatibility with the expectations related to the development of the TDABC, specifically with the mapping of the tasks performed and the recording of their time standards. The questions were classified in a standardized way according to the general characteristics of the study. The figure 2 below shows in detail the mapping of the interview process, i.e. the interview stages and the nature of the corresponding questions. The same questions were asked of several providers in the same ambulance category (basic).

Our concern is then to find the methodology best suited to master the process of pre-hospital transport of victims of road accidents by basic ambulance. The inventory of the equipment of the basic ambulance and the strategy of chaining the stages of maintenance (Table 1) allow us to be in the heart of the service of prehospital transport, to apprehend the process in a detailed way and to follow the operation in declared time. Our work will allow us to compare the concordance of the practices of prehospital transport by basic ambulance with the expected results and with those of the few studies on TDABC for prehospital transport.

Thus, the contributions of this work concern the interest of developing a cost calculation model, both

theoretical and practical, for the pre-hospital transport service of road accident victims by basic ambulance, by applying a more operational method of cost accounting (the TDABC). This model provides managers with relevant costs and reliable information to implement better management practices.

In the foregoing, we have presented the analytical framework of our research: a presentation and analysis of the contribution of Time-Driven Activity-Based Costing (TDABC) to the process of pre-hospital and hospital care, an overview of the characteristics and legal constraints of pre-hospital transport, the way in which we are going to associate the two concepts, TDABC and pre-hospital transport, developing our working method author of an approach adapted to the particularities of pre-hospital transport of victims of road accidents.

In the following, we aim to enrich the academic knowledge on TDABC in pre-hospital care. Starting from the reality of medicalized collection of victims of road accidents, we have a model in TDABC of cost calculation adapted to the various situations of prehospital transport of victims by basic ambulance. For the experimentation of the presented model, being the difficulties encountered, in particular the estimation of the time of the journey, and the expectations of the elaboration of the TDABC, we have chosen a journey constituted by a place of accident (black spot) and a hospital well defined in an urban area.

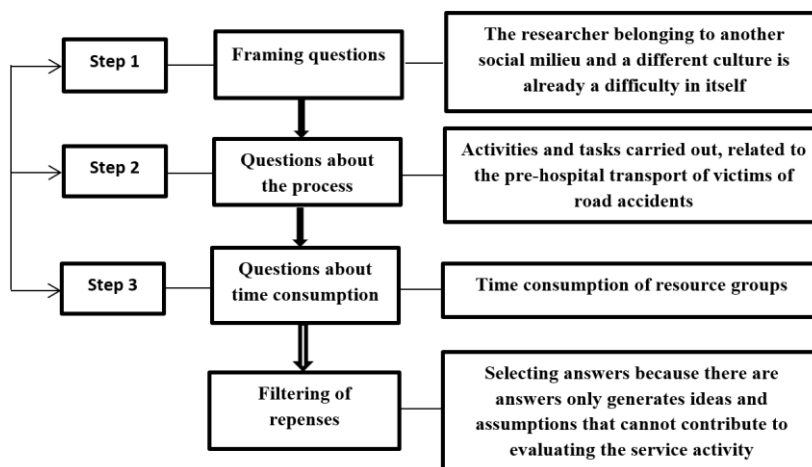


Fig. 2. The interview stages and the nature of the corresponding questions

At the end of this article, we will summarize the results obtained, taking into account the specific objectives of the study. The practical contributions and limitations of this research will be presented. We will also specify the main avenues of reflection for future research.

4. Implementation of the TDABC in the pre-hospital transport of road accident victims

4.1. Cost modeling of the pre-hospital transport trajectory in TDABC

The mapping of pre-hospital transport activities is essential to the process. We took note of the existing process maps in the health protocol for the care of victims. This was enriched by interviews with the main actors (ambulance technician, stretcher bearer). The identification of the normal capacities of the resource groups (vehicle, ambulance drivers), the activities carried out and the standard time consumed made our investigation difficult. However, thanks to the contribution of the different actors, the pre-hospital transport procedure could be described and schematized in main activities and tasks. This made it possible to code them and to develop time equations.

Let us recall that the journey of the care of victims by ambulance drivers is made up of several stages: journey from the civil protection to the place of accident, the embarkation, the journey to the place of destination (hospital), the disembarkation, and then the return of the ambulance crew to the civil protection. We find a multiplication of activities within the journey. We have thus managed to decompose the "ambulance driver" resource for the "pre-hospital

transport of the victim" activity into one variable relating to the journey (civil protection - accident site - hospital - civil protection) and 7 variables relating to the operations performed by the ambulance drivers. These variables make it possible to transcribe the complexity of the pre-hospital transport service of road accident victims by basic ambulance. In the figure 3, the complete list summarizes the main operations performed by the ambulance drivers in the trajectory of pre-hospital transport of road accident victims by basic ambulance.

Each activity variable is assigned a time T (in minutes), in order to structure time equations corresponding to the consumption of the capacity of the pre-hospital transport activity of road accident victims by basic ambulance. These times are averages of standard times of the different elements constituting these activities, based on a timing of the declared activity.

This mapping of the activity was presented for validation to the members of the basic ambulance team (ambulance technician, stretcher bearer) and to the expert in the field (the second author) for enrichment. However, the pre-hospital transport of victims of road accidents by basic ambulance is not the only activity of civil protection. Practically, the pre-hospital transport service provided pre-hospital interventions of victims in case of emergencies by other type of ambulance (emergency and resuscitation ambulance). These are all activities that generate other variables related only to the tasks at departure / destination. This generates other time equations to model other activities.

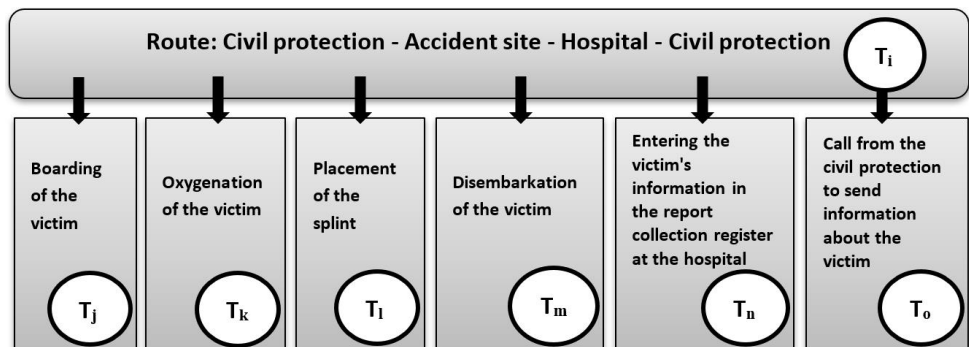


Fig. 3. Activity plan of a pre-hospital transport trajectory of road accident victims by basic ambulance and the corresponding time variable (T)

4.1.1. Estimated cost, practical capacity and unit cost per minute of the various direct resource groups

According to the TDABC model, it is necessary to know how long it takes to perform each activity and to identify the resource groups that perform them. It is also important to determine the total cost of the direct resource groups and their practical production capacity. We recall here that the resource groups are the ambulance workers (ambulance technician and stretcher bearer) and the vehicle (ambulance). Table 2 and 3 present respectively the way to calculate the cost per minute for the human and material resource groups.

Table 2. Cost per minute of human resource groups working directly on the pre-hospital transport route by the basic ambulance

	Ambulance technician	Stretcher Bearer
Salaries, benefits and social charges in MAD	S ₁	S ₂
Practical resource capacity in minutes	M ₁	M ₂
Cost / Practical capacity = Cost per minute	C ₁	C ₂

To determine the cost per minute for the human resource groups, Ambulance Technician (C₁) and Stretcher Carrier (C₂), we first extracted their annual salary (S₁ and S₂). This includes all benefits and payroll taxes paid by the facility. Finally, we were able to extract the time actually worked by the paramedics, which corresponds to the practical capacity of the paramedics (M₁ and M₂). From these hours, we could not deduct the break times in a day, because the paramedics are on alert and therefore, they are called to intervene at any time.

For the resource group cost per minute related to the vehicle (C₃), we must take into account all the annual depreciation cost (A). It was therefore possible to determine the cost per minute of this vehicle by the same rule as for the ambulance drivers, i.e., by dividing the annual depreciation cost (A) by the standard practical capacity (M₃), evaluated in minutes. The standard practical capacity was determined using the vehicle's hours of operation, which are all days of the year except for days reserved for vehicle maintenance. The cost per minute for this vehicle is shown in Table 3.

Table 3. Cost per minute of material resource groups directly involved in the pre-hospital transport process

	Vehicle
Annual amortization	A
Practical capacity in minutes	M ₃
Cost / Practical capacity = Cost per minute	C ₃

4.1.2. Calculation of the cost of activities attributable to direct resource groups

Once the cost per minute has been determined for each resource group, it is possible to quantify the direct labor cost of each task. This is done by multiplying the time in minutes required to complete the task by the cost per minute determined in Table 2, and doing so for each resource group. The Table 4 outlines the cost of each of the activities in the pre-hospital transport pathway in relation to the human resources working directly on the prehospital transport pathway.

Using all of this information, we were able to determine the total cost of the pre-hospital transport trajectory for all human resource groups, ambulance technician and stretcher bearer, directly involved in this trajectory. The Table 5 presents a summary of all direct costs and establishes the total cost of human resources.

Regarding the material resource group (vehicle) involved in the pre-hospital transport process, the vehicle must be used throughout the pre-hospital transport trajectory. The Table 6 shows the cost of this equipment for the journey. This cost was determined by multiplying the cost per minute (C₃) by the time to complete the round-trip transport trajectory (T_i).

4.1.3. Calculating the total cost of the pre-hospital transport path according to the TDABC model

The preceding steps yield the total financed cost model for the prehospital basic ambulance transport pathway determined using the TDABC method. The equation below summarizes a reconstruction of the total costs. In this equation, we recall that the variables are binomial, may or may not take a zero value depending on their occurrence. TDABC Total Cost Model of Prehospital Transport Pathway are:

$$C_1 (T_i + T_j + T_m) + C_2 (T_i + T_j + T_k + T_l + T_m + T_n + T_o) + C_3 T_i \quad (1)$$

Table 4. The cost of each of the activities related to the human resources working directly on the pre-hospital transport trajectory

Activities and tasks related to human resources groups	Human Resources Groups	Cost per minute	Time (T) spent in minutes by activity	Total Costs
Civil protection - Accident site - Hospital - Civil protection	Ambulance technician	C_1	T_i	C_1T_i
	Stretcher Bearer	C_2	T_i	C_2T_i
	Total cost			$C_1T_i + C_2T_i$
Boarding of the victim	Ambulance technician	C_1	T_i	C_1T_i
	Stretcher Bearer	C_2	T_i	C_2T_i
	Total cost			$C_1T_i + C_2T_i$
Oxygenation of the victim	Ambulance technician	C_1	0	0
	Stretcher Bearer	C_2	T_k	C_2T_k
	Total cost			C_2T_k
Placement of the splint	Ambulance technician	C_1	0	0
	Stretcher Bearer	C_2	T_i	C_2T_i
	Total cost			C_2T_i
Disembarkation of the victim	Ambulance technician	C_1	T_m	C_1T_m
	Stretcher Bearer	C_2	T_m	C_2T_m
	Total cost			$C_1T_m + C_2T_m$
Entering the victim's information in the hospital's report collection register	Ambulance technician	C_1	-	-
	Stretcher Bearer	C_2	T_n	C_2T_n
	Total cost			C_2T_n
Call from the civil protection administration to send information about the victim	Ambulance technician	C_1	-	-
	Stretcher Bearer	C_2	C_2T_o	C_2T_o
	Total cost			C_2T_o

Table 5. Total Direct Human Resource Costs

Activity	Cost per activity
Route: civil protection - accident site - hospital - civil protection	$C_1T_i + C_2T_i$
Boarding of the victim	$C_1T_i + C_2T_i$
Oxygenation of the victim	C_2T_k
Placement of the splint	C_2T_i
Disembarkation of the victim	$C_1T_m + C_2T_m$
Entering the victim's information in the hospital's report collection register	C_2T_n
Call from the civil protection administration to send information about the victim	C_2T_o
Total cost	$C_1(T_i + T_i + T_m) + C_2(T_i + T_i + T_k + T_i + T_m + T_n + T_o)$

Table 6. Total Direct Vehicle Costs

Activity	Cost per activity
travel costs: Civil protection - Accident site - Hospital - Civil protection	C_3T_i
Total cost	C_3T_i

4.1.4. Calculation of the cost attributable to indirect resource groups for each activity

For the rest of the personnel working in the different services of the civil protection, they have indirect tasks to the trajectories of pre-hospital transport, among others, cleaning of stretcher, disinfection of the interior of the vehicle, etc. These are all activities that generate other variables related, among others, to the mechanical or garage activity. This generates

other time equations to model other activities in TDABC.

For the costs incurred indirectly to the material resource group (vehicle), we have added in addition to the total cost mentioned above (1), the percentage of vehicle maintenance costs (oil change, tires etc.) to the trip. To do this, simply divide the total annual costs by the annual average of trips, also adding the average of fuel consumed corresponding to the number of kilometers traveled on the trip.

4.2. Model validation

The TDABC approach allows a modeling of the costs of pre-hospital transport of road accident victims. According to this model, it is necessary to know the time required to perform each activity. The objective is to fix the journey as a standard time. We are aware of the limitations of the travel time to and from the accident site (civil protection - accident site - hospital - civil protection). Faced with this situation and given that the accident sites are different in terms of distance to travel, we chose the Hassan II Boulevard in the city of Fez (henceforth referred to as BHII) as the accident site because it represents a black spot, the majority of which with minor injuries. The latter (BHII) extends over a distance of 454 linear meters and without exit on the sides for ambulances. The hospital center in which we conducted our study (hereinafter referred to as CHG) reserved for the reception of victims whose condition is not critical. The operation of collection of the victims of the road accidents at the level of the places of the boulevard HII does not have influence on the time of round trip: civil protection - BHII - CHG - civil protection.

Let us emphasize that the city of Fez has, according to the Compendium of statistics of road traffic injury accidents, recorded in 2018, 6073 injuries and 102 deaths. According to the Regional Directorate of Equipment and Transport of Fez, the BHII is a real black spot.

Recall that the above equation summarizes, for the entire process, the total TDABC cost of the pre-hospital transport pathway for traffic accident victims by basic ambulance. Each activity variable is assigned a time, in minutes. These times are averages of reported times, in order to calculate standard times.

According to the above equation, the trip (Civil Protection - BHII - CHG - Civil Protection) consists of a time (90 minutes). This time (90 minutes) is determined, according to the statements of the emergency physicians interviewed, on the basis of the average round trip.

The two following elements (boarding for lying down and boarding for sitting/standing) correspond to the same activity variable "boarding". We observe that the average time varies according to the victim's ability to stand up or not: 15 or 20 minutes. If there is a need for oxygenation of the victim or splinting,

and 24 minutes respectively are added. Disembarkation: 5 minutes. Other times are also associated with the activity "transport of victim", 5 minutes for the input of the information about the victim in the register of collection of declaration to the hospital center (CHG) and 4 minutes concern a call from the administration of the civil protection to send the information about the victim. The Table 8 gives the total cost of the victim's prehospital transport trajectory in four possible cases: victim in a sitting/standing position (does not need oxygenation or splinting), victim in a lying position (needs oxygenation), victim in a lying position (needs splinting), and victim in a lying position (needs oxygenation and splinting).

Table 8. Total cost in TDABC of the route: civil protection - BHII - CHG - civil protection according to different modalities

	Total cost of travel in MAD
Victim in position (sitting/standing)	217.47
Victim lying down needs oxygenation	224.31
Victim lying down needs splinting	225.45
Victim lying down needs oxygenation and splinting	226.59

The results found, represent the total cost in TDABC on a well-defined trip of the four cases mentioned above. The set of accident locations can be modeled according to changes in the trip time variables identified as explanatory of the time consumed. This allows for the development of a mapping of the costs of pre-hospital transport of traffic accident victims.

5. Discussion

5.1. Reflection on the contributions of the TDABC

The TDABC approach allows modeling of pre-hospital transport costs of road accident victims, but also of possible evolutions (new activities or tasks related to the pre-hospital transport service) thanks to time equations, as pointed out by several authors (Demeere et al., 2009; Kaplan and Anderson, 2004; La Villarmois and Levant, 2007; Robert S. Kaplan and Anderson, 2008; Siguenza-Guzman et al., 2013). According to these authors, TDABC provides the possibility to model complex operations (other activities), but also to perform simulations and benchmarking (Domingo et al., 2018). With the simulation option, organizations can mobilize the

TDABC to analyze and optimize the use of resources (Everaert et al., 2018). This allows different assumptions and possibilities to be considered when reorganizing the pre-hospital transport activity. Benchmarking is a technique that allows modeling the processes of medicalized patient pickup in a facility, based on the sharing of a common vision of the process and the associated costs within several facilities. Finally, this work shows that TDABC is feasible for pre-hospital transport, which opens up prospects for further development in all civil protection services (falls, drownings, shocks, burns, intoxications and other accidents). However, all the activities of the civil protection services are modeled according to additional variables, relative to the tasks at departure / destination, identified as explanatory of the time consumed. The constitution of groups of resources allows, then, to associate a cost to the different trips according to their time, but the interweaving of these variables leads to time equations that are sometimes more complex.

If the model we propose is computerized and programmed, it can be easily used to treat all similar cases and result in a cost calculation of all possible cases by the basic ambulance.

When the TDABC approach is used across a range of emergency services, decision makers are able to see the variation in costs between similar prehospital transport services and different routes for the same transport services, and the value of costs for each patient population category such as motor vehicle accident victims.

5.2. The TDABC: limitations and perspectives

The pre-hospital transport sector is generally dissatisfied in terms of the pricing of services and the possibilities of comparison available. This is an issue that is not developed in the current literature (Zerka and Jawab, 2020). This issue should be further investigated. Studies on contextual adaptation and experimentation in the field (Petit and Ducrocq, 2017) also seem to be necessary. However, this pre-hospital transport activity is totally absent from the activity-based pricing system. It would therefore be interesting to apply the TDABC in other establishments in order to be able to set rates and make such comparisons. In addition, the TDABC enables pre-hospital transport activity to be highlighted within the care pathway.

Beyond TDABC, the research shows several limitations of TDABC related to time measurement problems. The elaboration of the activity map (route and tasks) and the collection of time is a resource consuming phase. Moreover, (de La Villarmois and Levant, 2007) confirm that measuring time spent on services is complex because it remains unclear and unstable. The activity of pre-hospital transport of victims of road accidents is characterized by this variability of time, among other things, the distance to be covered, the metrological conditions, the nature of the damaged organ influence, to a large extent, the time actually consumed. For example, the time required to pick up the victim may vary depending on whether or not the victim is able to stand up. However, the times reported in this study are not statistically representative of each task. It would then be necessary to record the time consumed over a long period in an automated way. The repetitiveness of the tasks taken independently and the recording of the times consumed nevertheless make it possible to constitute standards of time or to arrive at such means and to relativize this limit for our case. Exploiting opportunities, such as responding to other disasters (after the victim has been discharged from the hospital), are hidden performance gains. These opportunities are not programmed, especially since they are not recorded. It is easily conceivable to integrate them into the time equations. To do this, time intervals must be used, such as the departure interval from the hospital to the ambulance depot. As a result, the service can save time and reduce the cost of the journey (hospital - civil protection) in order to optimize the management of the pre-hospital transports performed.

6. Conclusions

The costs of pre-hospital transport of road accident victims influence to a large extent the costs of the civil protection pre-hospital transport service. In order to achieve the overall cost control of the pre-hospital transport services for road traffic victims, civil protection must focus on the pricing of services. The TDABC can be used to measure the costs of processes that are currently used for pre-hospital patient pickup and treatment. The TDABC provides the methodology to accurately calculate actual costs based on total resource utilization so that decision makers know, among other things, the value of the costs of the benefits available to victims of motor

vehicle accidents. Once the true costs of pre-hospital transport of traffic accident victims by basic ambulance are known, other pre-hospital transport processes can be addressed in future research (resuscitation ambulance).

The usefulness and effectiveness of the TDABC approach, which is reflected in the significant improvement in the value of victims of road accidents, opens up new tracks for reflection on other civil protection activities, including pre-hospital transport processes for other categories of patients, the garage activity, etc. As is the case in other sectors of activity, the TDABC will give civil protection the means to design and implement best practices to improve the value of victims and the optimization of its course.

References

- [1] Alcouffe, S., Malleret, V., (2002). Les fondements conceptuels de l'ABC à la française. *Echnologie et Management de l'information: Enjeux et Impacts Dans La Comptabilité, Le Contrôle et l'audit*.
- [2] Au, J., Rudmik, L., (2013). Cost of outpatient endoscopic sinus surgery from the perspective of the Canadian government: a time-driven activity-based costing approach. *International Forum of Allergy & Rhinology*, 3, 748–754. doi: 10.1002/alr.21181.
- [3] Baker, J. J., (1998). Activity-Based Costing and Activity-Based Management for Health Care. *Jones & Bartlett Learning*.
- [4] Bebkiewicz, K., Chlopek, Z., Sar, H., Szczepanski, K., Zimakowska-Laskowska, M., (2021). Assessment of impact of vehicle traffic conditions: urban, rural and highway, on the results of pollutant emissions inventory. *Archives of Transport*, 60, 57–69. doi: 10.5604/01.3001.0015.5477.
- [5] Campanale, C., Cinquini, L., Tenucci, A., (2014). Time-driven activity-based costing to improve transparency and decision making in healthcare: a case study. *Qualitative Research in Accounting & Management*, 11, 165–186. doi: 10.1108/QRAM-04-2014-0036.
- [6] Coats, T. J., Davies, G., (2002). Prehospital care for road traffic casualties. *BMJ*, 324, 1135–1138. doi: 10.1136/bmj.324.7346.1135.
- [7] De La Villarmois, O., Levant, Y., (2007). Le Time-Driven ABC: la simplification de l'évaluation des coûts par le recours aux équivalents. *Un essai de positionnement. Sciences de l'Homme et Société / Gestion et Management*.
- [8] Demeere, N., Stouthuysen, K., Roodhooft, F., (2009). Time-driven activity-based costing in an outpatient clinic environment: development, relevance and managerial impact. *Health Policy*, 92, 296–304. doi: 10.1016/j.healthpol.2009.05.003.
- [9] Domingo, H., Eggrickx, A., Naro, G., Bourret, R., (2018). Le Time Driven Activity Based Costing (TDABC), modèle de calcul de coût adapté au parcours de soins des maladies chroniques ? *Gestion et Management Public*, 6, 71–93.
- [10] Everaert, P., Bruggeman, W., Sarens, G., Anderson, S. R., Levant, Y., (2018). Cost modeling in logistics using time-driven ABC experiences from a wholesaler. *International Journal of Physical Distribution & Logistics Management*, 38, 172–191. doi: 10.1108/09600030810866977.
- [11] Fricchi, Y., Jawab, F., Boutahari, S., (2019). The Mixed-Method 5W2D Approach for Health System Stakeholders Analysis in Quality of Care: An Application to the Moroccan Context. *International Journal of Environmental Research and Public Health*, 16. doi: 10.3390/ijerph16162899.
- [12] Jawab, F., Fricchi, Y., Boutahari, S., (2018). Hospital Logistics Activities. *International Conference on Industrial Engineering and Operations Management*, 3228–3237.
- [13] Kaplan, R. S., Anderson, S. R., (2004). Time-driven activity-based costing. *Harvard Business School Press*.
- [14] Kaplan, R. S., Anderson, S. R., (2007). time-driven activity-based costing: a simpler and more powerful path to higher profits. *Harvard Business School Press*.
- [15] Kaplan, R. S., Porter, M. E., (2011). How to solve the cost crisis in health care. *Harvard Business Review*, 89, 56–61.
- [16] Kee, R., (2012). Measuring & Managing the Cost of Governmental Services: A Case for Time-Driven Activity-Based Costing. *The Journal of Government Financial Management*, 61, 38–41.
- [17] La Villarmois, O. De, Levant, Y., (2007). Une évolution de l'ABC: filetime-driven ABC.

- Revue Française de Comptabilité*, 405, 26–32.
- [18] Lamuraud, K., Lhuillery, S., (2016). *Endogenous technology adoption and medical costs. Health Economics*, 25, 1123–1147. doi: 10.1002/hec.3361.
- [19] Lipscomb, J., Yabroff, K. R., Brown, M. L., Lawrence, W., Barnett, P. G., (2009). Health care costing: data, methods, current applications. *Medical Care*, 47. doi: 10.1097/MLR.0b013e3181a7e401.
- [20] Mclaughlin, N., Burke, M. A., Setlur, N. P., Niedzwiecki, D. R., Kaplan, A. L., Saigal, C., Mahajan, A., Martin, N. A., Kaplan, R. S., (2014). Time-driven activity-based costing: a driver for provider engagement in costing activities and redesign initiatives. *Neurosurg Focus*, 37. doi: 10.3171/2014.8.FOCUS14381.
- [21] Moufad, I., Jawab, F., (2019). A study framework for assessing the performance of the urban freight transport based on PLS approach. *Archives of Transport*, 49, 69–85. doi: 10.5604/01.3001.0013.2777.
- [22] Oklu, R., Haas, D., Kaplan, R. S., Brinegar, K. N., Bassoff, N., Harvey, H. B., Brink, James A., Prabhakar, A. M., (2015). Time-Driven Activity-Based Costing in IR. *Journal of Vascular and Interventional Radiology*, 26, 1827–1831. doi: 10.1016/j.jvir.2015.07.007.
- [23] Petit, N., Ducrocq, C., (2017). Calcul des coûts d'un service de transport hospitalier en TDABC. *Gestion et Management PAPApublic*, 5, 59–81.
- [24] Robert S. Kaplan, Anderson, S., (2008). La méthode abc pilotée par le temps. *Eyrolles-Éd. d'Organisation*.
- [25] Shankar, P. R., Anzai, S. E. H. Y., (2020). Time-driven activity-based costing in radiology: an overview. *Journal of the American College of Radiology*, 17, 125–130. doi: 10.1016/j.jacr.2019.07.010.
- [26] Siguenza-Guzman, L., Abbeele, A. Van Den, Vandewalle, J., Verhaaren, H., Cattrysse, D., (2013). Recent evolutions in costing systems: A literature review of Time-Driven Activity-Based Costing. *Review of Business and Economic Literature*, 58, 34–64.
- [27] Sophie, H., Werner, B., (2010). Identifying operational improvements during the design process of a time-driven ABC system: the role of collective worker participation and leadership style. *Management Accounting Research*, 21, 185–198. doi: 10.1016/j.mar.2010.01.003.
- [28] Tafti, M. F., Reza, R., (2021). Development of models to study traffic accidents on the final sections of access roads to the cities: a case study of three major Iranian cities. *Archives of Transport*, 59, 129–148. doi: 10.5604/01.3001.0015.2646.
- [29] Tang, D., Loze, M. T., Zeh, H. J., Kang, R., (2010). The redox protein HMGB1 regulates cell death and survival in cancer treatment. *Autophagy*, 6, 1181–1183. doi: 10.4161/auto.6.8.13367.
- [30] Troyer, G. T., Brashear, A. D., Green, K. J., (2005). Managing corporate governance risks in a nonprofit health care organization. *Journal of Healthcare Risk Management*, 25, 29–34. doi: 10.1002/jhrm.5600250309.
- [31] Udpa, S., (1996). Activity-based costing for hospitals. *Health Care Management Review*, 21, 83–96.
- [32] Zehmed, K., Jawab, F., (2021). The performance of tramway service from the users' viewpoint: A comparative analysis between two Moroccan cities. *Archives of Transport*, 60, 7–21. doi: 10.5604/01.3001.0015.5223.
- [33] Zerka, A., Jawab, F., (2020). Calculation of the costs of health care services for road accident victims in TDABC: a systematic review of the literature. *International Colloquium of Logistics and Supply Chain Management*, 1–7. doi: 10.1109/LOGISTIQUA49782.2020.9353894.