Risky Time Driven Activity Based Costing in a Medical Center: A Development, Implementation and Simulation based Optimization Approach

Morteza BAGHERPOUR[1]

Abstract: Nowadays, with the development of enterprises and increases in competitions, management needs to do more actual investigation and in-depth analysis. Meanwhile, practical information about the service cost of each client/product and determining free capacity of resources are highly desirable, in order to detect which of clients/products are more profitable. There are several available costing systems in the literature; however till the present time, none of them are considered to have a probabilistic nature associated with a business environment. In this paper, a standard time driven activity based costing (TDABC) is combined with a simulation model, proposing a novel algorithm called Risky TDABC. The three risky factors which are considered in this study are: 1.Resource capacity 2.Estimated activity time 3.The required quantity of an activity. Additionally, the idle time of each resource is also determined, an aspect which has not been considered in the standard TDABC system. Therefore, by applying a resource configuration management in a medical center, different scenarios are developed and compared to each other, finding the best-known alternative through a simulation based optimization approach. The obtained results are apparently found to be more actual and reliable. The proposed model is finally validated and successfully implemented in a healthcare center department.

Keywords: risk; time driven activity based costing; simulation based optimization; healthcare; idle time

JEL Classification:

1. Introduction

Nowadays, there has been a great evolution in the costing systems. These progresses can be categorized within three major systems: the traditional (standard)-costing systems, Activity-Based Cost system (ABC), and Time-Driven Activity-Based Costing (TDABC).

The Traditional costing systems mostly consist of two types of costs: direct costs and overhead costs 1. These systems are useful when there is a mass production, with a small variety of products and services expected. As companies moved towards customer focusing policies, there was a need for presentation of a wide variety of products as well as services. This is where the traditional systems mostly failed and so researchers were urged to find a solution 2.

The ABC costing system found an answer to such cases. There are some major steps in this method. First we should identify the activities. These activities consume resources. Then the cost pools should be identified, activity cost pools are pools of individual costs which have the same cost drivers. Activities are traced to cost pools. An overhead rate is then calculated for each cost pool; therefore, overhead costs can be allocated to each product according to the use of each cost pool 3. However this method has also limitations to its use; such as its high cost, time consuming data collection, difficulty in updating and integration 4.

As a result, we needed a new method to overcome the aforementioned limitations and that is why Time-Driven Activity-Based Costing was introduced by Kaplan and Anderson as a simple and accurate approach. Here two estimates are given 4:

The unit cost of supplying capacity = (Cost of capacity supplied) (practical capacity of resources supplied)
(1)

[1] Department of Industrial and Systems Engineering, University of Pretoria, South Africa, mortezabagherpour@gmail.com

When activities are identified, their time usage of each resource is multiplied by the resource unit costs and the total cost assigned to the activity is then calculated. These costs are rolling up to find the total cost of a process. However, sometimes for the unit time estimation, mathematical equations are developed 4.

Through reviewing the literature on costing systems especially the TDABC, lack of consideration of probabilistic modeling and risky condition within TDABC system was found. The major risk factors affecting costing obtained by TDABC are given below:

1. Resource capacity;
2. Estimated activity time (activity);
3. The required quantity of an activity.

Thus, here we introduce a new approach entitled "Risky Time-Driven Activity-Based Costing (RTDABC). The above aforementioned problems are solved using simulation analysis.

2. Literature Review

Harvard Business School professors, Cooper R., Robert S. Kaplan and Steven R. Anderson are pioneer researchers in costing systems. They have developed new methods and approaches in business and practical environment 5.

In 1992, when ABC systems were introduced, R. cooper and R.S Kaplan described a conceptual basis of this method and explained its design and use. They introduced the following equation to define the ABC systems as resource usage models.

Activity Availability = Activity Usage + Un-used Capacity (2)

Providing a new knowledge which can be implemented in a practical environment and useful for managerial action is important and needs a deep understanding of academics and the case study. Argyris, C. and R. S. Kaplan gave advices on this matter in 1994.

During the last four decades information economics and decision science have been gradually exploited in accounting science. ABC and BSC have good compatibility and can be used contemporary in practice 6.

Teemu malmi explains the reasons behind ABC failures in organizations especially ones with high variety in stakeholder interests. He also shows the reasons of resistance in a company 7.

The effectiveness of ABC systems can be improved by integrating this method to other business analyzes tools such as business process modeling and analytical hierarchy approach. Thus, the method would be more practical and is used to determine correct cost of operations in a land transportation company 8.

Just one costing system is not normally enough, while companies need to manage three different functions. ABC can be used in different levels of strategic management and can be integrated with Enterprise Systems. It also can be used for budgeting and transfer pricing as well 9.

Logistics costs has been increased in the recent years, thus, they gain high attention of companies. These costs can be analyzed by an integrated tool of TDABC and Theory of constraints. Theory of constraints has a perspective of optimizing logistics processes according to their costs 10.

Cost management systems have different philosophies. Two of them are TDABC and Resource Cost Analysis (RCA). These two philosophies have different uses. For instance, according to their relationship with other information systems, TDABC is system independent and RCA is ERP-compliant 11.

Subordinate managers can be trained with TDABC methodology, as this method can improve manager's visibility, ownership and motivation; it can reduce the amount of budget slack 2.

3. Problem Statement

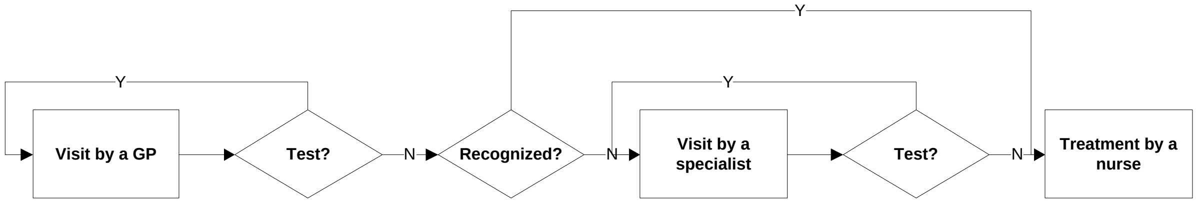
In this paper, a simulation based costing approach in a healthcare center is studied. According to the development of healthcare centers around the world there is an increasing need to study costs and define which departments/clinics and / or which patient types are profitable.

There are diverse patients with different needs so a healthcare center has various departments to serve the patients' needs.

The article focuses on RTDABC through a medical department. This department has 3 kinds of resources, l general physicians (GP), m specialists and n nurses. There are p patients for this department. To study costs of each patient, first we need to find the flowchart of each patient by the use of business process modeling.

The flowchart of the patients shows loops and uncertainties in a medical department. An example of these processes is displayed in Figure 1.

Figure 1. An example of the processes in a healthcare center.



To consider this flowchart we need an appropriate costing system which is able to consider loops and probabilities associated with modeling procedure. The standard costing system is TDABC but this system did not consider loops and uncertainties. It is needed to develop a TDABC system including re-works (i.e. patient follow-up) as expressed in Fig.1.

4. Solution Procedure

In this paper, a new methodology is presented as follow:

1. Identify activities; a client is served in a process which is included from a group of activities.

2. Match activities with resources

3. Create time equations and determine time usage of each activity from different resources (risky), table.1, the time that an activity exploits a resource usually is not constant.

4. Calculate cost of each activity per unit of time, an activity exploits different resources in various periods, using each resource causes cost and their sum would be cost of the activity.

Cost of the activity= Cost rate of resource 1 activity time usage from resource 1+ Cost rate of resource 2 activity time usage from resource 2+… (3)

5. Define different clients; enterprises usually have more than one client for their product or service.

6. Estimate Number of each client (risky), this number can't be firmly determined tables 2 and 3.

7. Identify witch activities are required for each client, each client requests for different activities.

Cost of the client= Cost of activity 1+Cost of activity2+… (4)

This algorithm is called Risky TDABC or RTDABC. Our goal here is to execute RTDABC in a Healthcare center. There are different departments in a clinic and each department has different kinds of patients and so various resources are required to serve these patients.

To serve different types of patients, diverse activities are needed and activities use resources to be performed. Profitability of each patient depends on the required activities and the ordered quantity or number of patients. In this article, ordered quantity is considered as a risky factor. We then simulate flow of different patients in the department with three risky quantities, including capacity of each resource, time usage of activities and number of different patients.

5. Case Study

5.1. System description

According to the importance of the emergency department (ED) in medical systems, the proposed algorithm is implemented through an ED. This department is a 24 hours active system. There are 3 shifts, morning, evening and night. We focus on night shift which begins at 8 pm and ends at 8 am. The process begins when a patient arrives to the department and ends when the patient leaves the department. There are 2 kinds of patients in ED, patients' type 1 are critical ones who need emergency managements. They have the highest priority in the ED. Patients type 2 should be visited by doctors and remain under observation or follow up, till their final diagnosis. Flowcharts of these patients are shown in Fig.2 and Fig.3 and in upcoming sections we will explain the charts in detail.

Employed resources of ED are given as below:

1. General physicians or GPs.
2. Nurses;
3. Specialists.

5.2. Data collection

The data was gathered through interviews with the manager and head of the department. In addition to the interviews we prepared questionnaires which were filled out by the nurses during a 2 month period. These data were given to the Input analyzer part of Arena® software and the distribution of processing times and the arrival rate of each patient were determined. They are presented in Tables 1, 2 and 3. The arrival rate of patients type 1 and 2 is Poisson with the rate of , it is calculated for each 3 hours.

5.3. Simulation modeling

The flowcharts of the patients were simulated in Arena® software. The Arena models are shown in figs 5 and 6.

The flowchart of the patient type 1 is explained as follows:

1. Patient Arrives to the ED;
2. The patient is revived by a specialist and 3 nurses;
3. The patient is transferred to another department by a nurse.

The flowchart of patient type 2 is explained as follows:

1. Patient Arrives to the ED;

2. He/she visits The GP;

3. The GP considers if he/she needs any tests.

4. If yes, a nurse does the test and again the GP observes the test results. Then the GP checks if he has a diagnosis for the illness or not. If yes he orders the treatment method and the nursing process for treatment of the patient starts. The treatment process may replicate several times because after each treatment the nurse investigates whether the patient is well or not.

5. If no test is needed, the GP considers if he recognizes the illness or not. If yes he orders the treatment method and the nursing process for treatment of the patient starts, just like the previous part, if the GP does not diagnose the illness, he refers the patient to the specialist.

6. Now the specialist visits the patient, here also he may order some tests which are done by nurses. The specialist orders the treatment method and the nurse will continue the treatment process. The treatment process may replicate several times as previous pointed out, because after each treatment the nurse investigates if the patient is in good health or not. If he was fine, he will be discharged to home.

Table 1. Time Distribution for the processes

Time distribution (min)	Process
Uniform(10,15)	Primary visit by a GP
Uniform(17,25)	Primary visit by a specialist
Triangular(4,5,6)	Doing a test
Triangular(6,7,8)	Doing a special test
Uniform(6,11)	Revisit by a GP
Uniform(12,19)	Revisit by a specialist
Uniform(3,10)	Treatment process
Triangular(80,90,100)	Delay to see the treatment result
Triangular(25,35,45)	Revival process
Uniform(3,7)	Release or transfer to another department

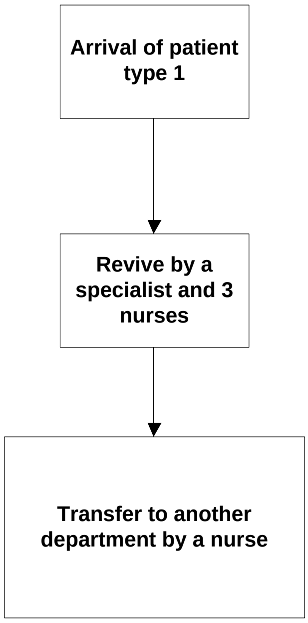
Table 2. Arrival rate of patient type 1 (Poisson with the rate of $\lambda(t)$ in three hours)

Time (hour)	Arrival rate
20-23	1
23-2	1
2-5	1
5-8	2

Table 3. Arrival rate of patient type 2 (Poisson with the rate of $\lambda(t)$ in three hours)

Time (hour)	Arrival rate
20-23	4
23-2	5
2-5	4
5-8	3

Figure 2. Flowchart of the patient type 1



6. Result of the proposed RTDABC

According to the algorithm and the Arena model, calculations were performed. We will explain the case according to the algorithm:

1. Identify resources: there are three resources in the ED, including GPs, nurses and specialists.

2. Estimate practical capacity of resources supplied (risky): for instance, there are 6 nurses, each nurse works 10.5 hours per day and 315 hours per month, so 6 nurses work 1890 hours or in other words 113400 minutes per month. The practical capacity of nurses is estimated to be 80% so the practical minutes per month that nurses are available is 90720, details are in table 4.

3. Determine total cost of each resource: for instance there are 6 nurses here and their salary is 8000 units of money per month, so the total cost for this resource is 48000 units, all data are presented in table 4.

4. Calculate cost of resource per unit of time, in table 4.

Cost of the resource per unit of time (cost rate of the resource) = (total cost of the resource) (practical capacity of the resource)

For instance: Nurses cost rate = 48000 90720= 0.53

5. Identify activities: there are two patient types, so we have two general processes, each process has its own activities, and we address these processes and activities in Figs 2 and 3.

6. Adapt activities with resources.

Figure 3. Flowchart of the patient type

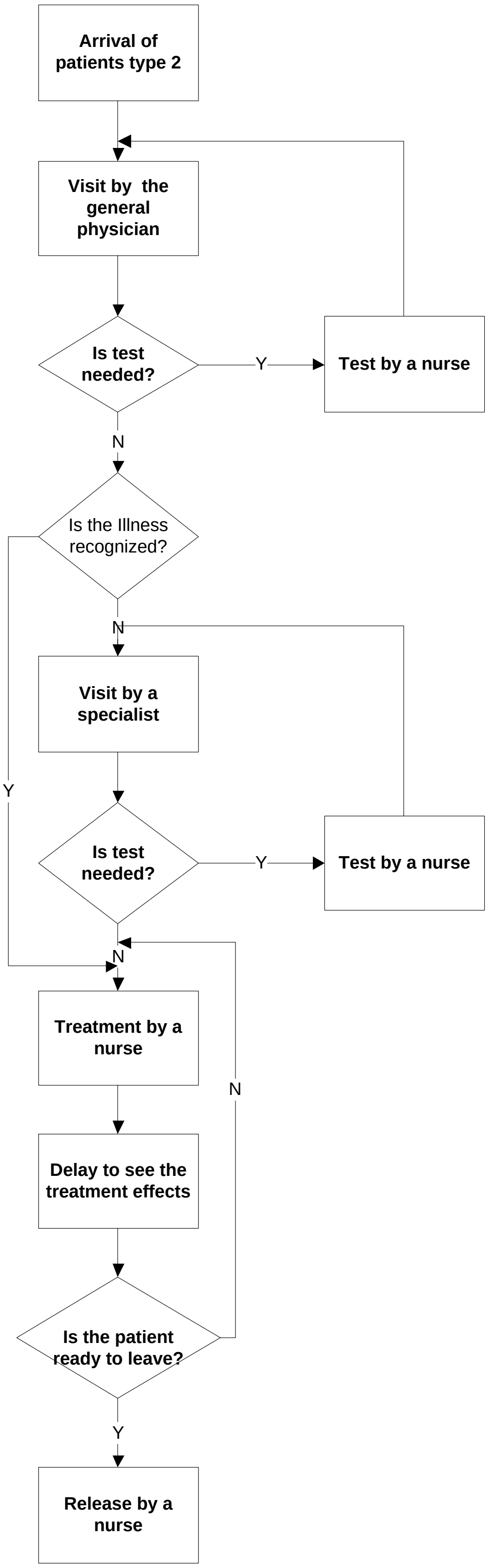


Figure 4. Defining the arrival rate of each patient, Poisson with the rate of 4 arrives in three hours

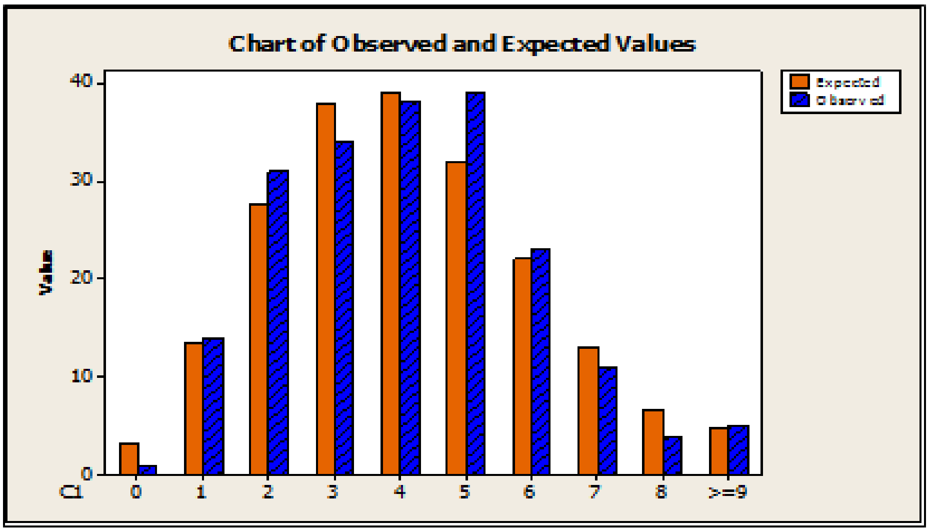


Figure 5. Arena model for the flowchart of patients type 1

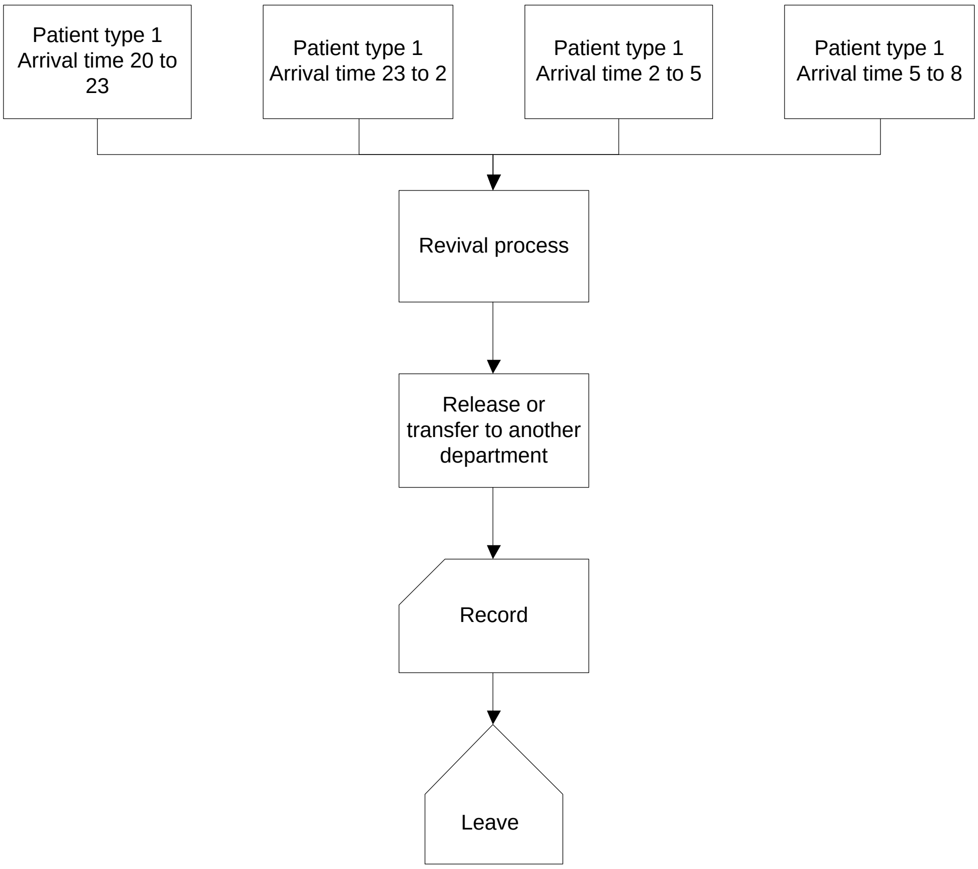
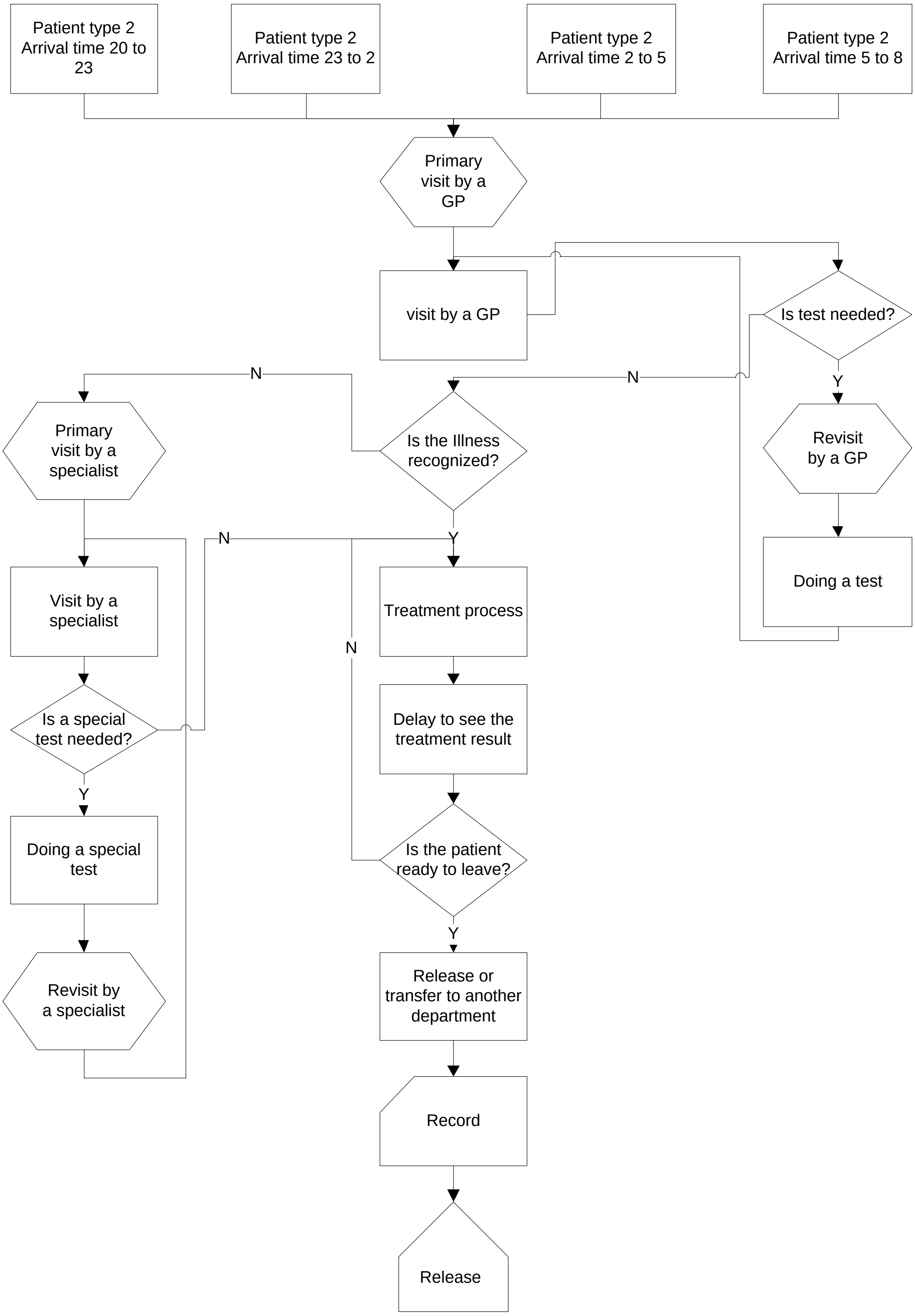


Figure 6. Arena model for the flowchart of patients type 2.



7. Create time equations and determine time usage of each activity from different resources (including risky condition): Input analyzer part of Arena simulation software determines time distribution of each activity that utilizes a resource, there are some activities which use more than one resource.

8. Calculate cost of each activity per unit of time, equation 3.

9. Define different clients: In this case clients are two patient types, patients' type 1 are critical ones who need emergency managements and should be revived. Patients' type 2 should be visited by doctors and remain under observation till they are discharged.

10. Estimate the number of each client (at risky condition): To estimate the number of each client, as they come by chance it's needed to define their arrival rate. It's observed that their arrival rate changes nearly each 3 hours. Arrival rate of each patient is displayed in tables 2 and 3.

11. Identify which activities are required for each client, equation 4: As mentioned above, we have two general processes, because these processes are probabilistic and have some loops, they should be simulated, and through simulation a lot of required information is generated. The Arena software determines the total time that each patient utilizes the different resources, as calculated in table 5, time usage of each resource for all patients in a month is multiplied by the resource cost rate, It is called the whole cost in a month for a patient type, after dividing it to the average number of the patients in a month, the average cost of each patient type is obtained.

7. Result Discussion

7.1. Research findings

1. Activities required to be done for each patient were determined and they were matched with the required resources.

2. Time distribution of each activity and the arrival rate of each patient were defined.

3. A risky environment in a healthcare department was modeled and its costs were analyzed.

4. In table 4 cost rate of each resource is computed.

5. In table 5 average cost of each patient is calculated.

6. The head of the center can compare costs of each patient with his income to define if he is profitable or not. This information affects future decisions about development of the enterprise.

7. Idle capacity of each resource is specified. This finding is continued in the following parts.

7.2. Comparative Results

In this section, results obtained by the new algorithm are compared to the results of standard TDABC on the ED case. TDABC doesn't consider loops and uncertainties so the flowcharts change as below in order to analyze the situation by this method. Times are assumed to be constant.

In fact the results of the RTDABC are much more actual than those observed by the standard TDABC because it did not consider loops and replicates and probabilistic inherent of such problems through modeling. Below equation can be defined to determine the difference between these two numbers, their difference is Risk cost which is not considered in TDABC. Calculations are made in table 6. Resources cost rate doesn't change and is the same as table 4.

TDABC cost + Risk cost = RTDABC cost (5)

8. RTDABC Development Considering Idle Resources

The standard TDABC doesn't normally consider idle resources cost; in fact each resource has some idle time because the whole capacity is not fully used. In an enterprise, resource costs depend on their attendance in the center not on the hours they work so somehow we should consider this cost. TDABC computes costs based on the time resources work or the time clients consume resources but in an enterprise there are other costs for idle time of each resource, Hence it's needed to develop a system which considers this overhead cost in our profitability calculations.

Figure 7. Flowchart of patients type 1 in a definite situation to analyze by TDABC system.

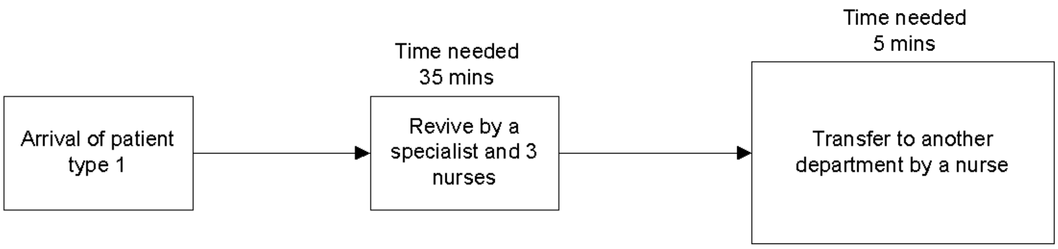
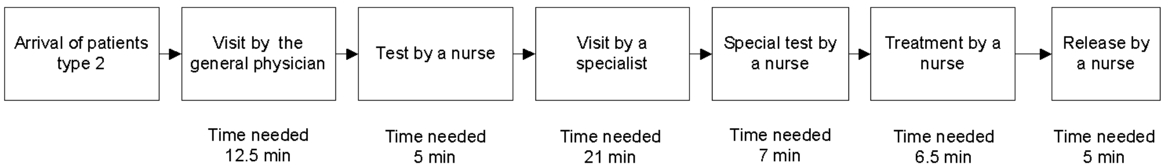


Figure 8. Flowchart of patients type 2 in a definite situation to analyze by TDABC system.



How could we share this overhead cost on each client type? To clarify this issue, the algorithm is explained on the healthcare case study. In this study idle time of each resource is shared with the two patient types based on the time each patient uses resources in a month. For instance in this case there are two patient types and three resources, in resources for example there are nurses, time usage of nurses by patients type 1 in a month is 20208 and this time used by patient type 2 is 16330, Idle time cost share rate is calculated as below:

Client type 1 idle time cost share rate = (Client type 1 usage of the resource)   (client type 1 usage of the resource + client type 2 usage of the resource+…) (6)

Patient type 1 idle time cost share rate = 20208   (20208+16330) = 0.55

Patient type 2 idle time cost share rate = 16330   (20208+16330) = 0.45

And the Equation No.4 is developed as below to find the cost of each client:

RTDABC cost + idle resource cost = total assigned cost (7)

For detailed calculations refer to tables 7 and 8.

Table 4. Calculating Cost per min of each resource

Resources	Number of each resource	Cost of each resource unit in month	cost of each resource in month (Cost of each resource unit in month × Number of each resource)	Work hours in month (30 × (12-1.5) × Number of each resource)	Work min's in month	Practical capacity	Practical min's in month (Practical capacity × Work min's in month)	Cost per min (cost of each resource in month ÷ Practical min's in month)
GP	2	15000	30000	630	37800	80%	30240	0.99
Nurse	6	8000	48000	1890	113400	80%	90720	0.53
Specialist	2	50000	100000	630	37800	80%	30240	3.31

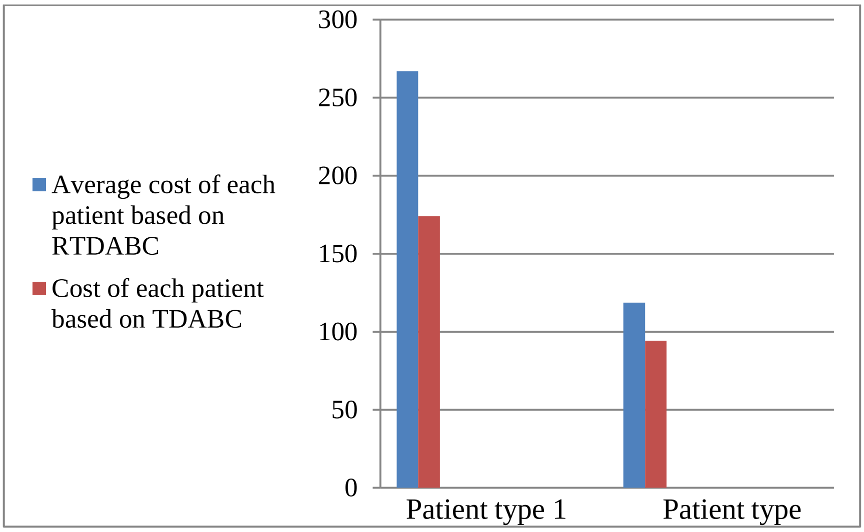
Table 1. Calculating Average cost of each patient Based on RTDABC

Patient type	Resources	Time usage of each resource for each patient	Resource cost per min	Total Cost of each patient from different resources in month	Average number of each patient	Average cost of each patient
	GP	0	0.99	0		
1	Nurse	20208	0.53	10692	120	267
	Specialist	6456	3.31	21350		
	GP	20146	0.99	19986		
2	Nurse	16330	0.53	8640	480	119
	Specialist	8579	3.31	28369		

Table 2. Calculating Average cost of each patient Based on TDABC

Patient type	Resources	Resource cost per min.	Activities							Cost of each patient
			visit by a GP	Doing a test	visit by a specialist	Doing a special test	Treatment process	Revival process	Release or transfer	
	GP	0.99								
1	Nurse	0.53						105	5	174
	Specialist	3.31						35		
	GP	0.99	12.5							
2	Nurse	0.53		5		7	6.5		5	94
	Specialist	3.31			21					

Figure 9. Comparative chart of Costs based on RTDABC and TDABC



When resources are generally decreased, RTDABC cost doesn't change but the idle resource cost decreases because resources may be busier, but the point that should be considered here is that as resources decrease patients will have to wait a longer time to be visited, which brings about some dissatisfaction, leading to decrease in the number of clients in time. This impact factor depends on the priority of the client, for instance regarding patients’ type 1, each second is important because of their critical situations but patients’ type 2 can wait for some time, thereupon impact factor for patients’ type 1 is much higher than that for Patients’ type 2, High priority clients, that means when they appear in ED all other clients will wait till they are checked, hence their waiting time is lower than the other. Waiting time of each patient type is reported in the simulation software, it is the total time that a patient has passed a process and is waiting for the next process or he has just arrived and is waiting for starting the first process. Details could be found in tables 9 and 10.

Waiting time cost for clients type 1 = Clients type 1 waiting time   impact factor for the clients type 1 waiting time (10)

Apparently waiting time of the clients doesn't cause any costs for the enterprise but in reality waiting time causes dissatisfaction that negatively affects clients' outlook. The department doesn't pay any cash for it, however it should be considered in the analysis.

According to the calculations in table 10, it's found that the best configuration of human resources in this department is to have 2 general physicians, 6 nurses and 2 specialists.

10. Conclusion Remark and Further Recommendation

Profitability and costing is a favorable subject to managers, they request for detailed information about costs and profits of each client and for the department and enterprise as a whole. To generate detailed financial information different costing systems are presented, although there have been great developments in costing systems in recent years; analyzers have a long way to satisfy managers with reliable financial information.

In this study, the authors wish to get closer to this point by developing a new algorithm and implementing it in a business environment. The business that is chosen for this subject is a healthcare center due to their probabilistic situation which makes it hard to analyze.

The first part of the study focuses on the analysis of a risky environment by proposing a new algorithm which is called RTDABC, this algorithm considers loops and probabilities in a practical situation. One main result of this algorithm is to find the average cost of each patient just based on their resource consumption and the second one is that this algorithm defines idle time of each resource which should be considered in the cost calculations and gives the manager the opportunity to think on these idle resources for future decisions, tables 4 and 5.

The second part of the study seeks to consider idle resources in calculations, it's true that when resources are idle clients don’t use them but the enterprise spends money on each minute of their attendance in the company, tables 7 and 8.

The third part of the article seeks to find the best configuration of resources which optimizes idle hours of the resources and waiting time of the patients. At the end, the best resource configuration and cost of each patient in that configuration is computed, the income from each client is specified, and hence simply the gross profit of each client can be determined, tables 9 and 10.

Considering cost of quality through modeling procedure and its effect on total assigned costs can be considered as a potential future work.

Table 9. Calculating average cost of each patient from three causes, Risks, idle resources and waiting time

Scenario	Configuration of the resources	Patient type	Average idle time cost	Average cost from RTDABC	Cost impact factor for the waiting time	Waiting time for each patient type	Waiting time cost	Average number of each patient	Average waiting time cost for each patient	Average cost of each patient
1	2 GPs, 6 nurses and 2 specialists	1	312	267	1000	10	10000	120	83	662
		2	107	119	10	1780	17800	480	37	263
2	2 GPs, 5 nurses and 2 specialists	1	275	267	1000	55	55000	120	458	1001
		2	100	119	10	2230	22300	480	46	265
3	2 GPs, 6 nurses and 1 specialists	1	133	267	1000	55	55000	120	458	858
		2	48	119	10	3600	36000	480	75	242

Table 10. Calculating average scenario profitability

Scenario	Configuration of the resources	Average cost of each patient	Average income from each patient	Profitability of each patient	Average number of each patient	Profitability of the department from each patient type in a month	Profitability of each scenario
1	2 GPs, 6 nurses and 2 specialists	662	1000	338	120	40512	53400
		263	290	27	480	12888	
2	2 GPs, 5 nurses and 2 specialists	1001	1000	-1	120	-63	11900
		265	290	25	480	11963	
3	2 GPs, 6 nurses and 1 specialists	858	1000	142	120	16983	40200
		242	290	48	480	23217	

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