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TDABC Capabilities for performance measurement: A case study in a manufacturing context

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TDABC Capabilities for performance measurement: A case study in a manufacturing context

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Abstract

Supply chain costing presents a sophisticated alternative to traditional costing allowing an accurate cost estimation and effective decision making. In exploring different techniques, TDABC was not explored extensively compared to its peers. In addition to the infancy of the technique, there is an on-going debate about the capability of the TDABC specifically in manufacturing context. The present study contributes to the debate by applying TDABC at the logistics function of a manufacturing site and assesses it capability to measure performance in the stated context.
Keywords: TDABC, Performance, Logistics, Case study

1.Introduction

In times of disruptions and uncertainty, such as Covid-19, the importance of managing supply chain costs (SCC) is emphasised since these costs directly impact managerial decision-making and the company's survival. The SCC literature has addressed different costing accounting techniques (CAT) to control, monitor and assess the operational performance, such as Activity-Based Costing (ABC), Total Cost of Ownership, Life cycle costing, to name a few. These techniques presented an alternative to traditional costing that falls short in: depicting a true cost-image, reflecting the real performance and impacting decision-making making [1], [2]. The expanding SCC literature showed a trend in adopting specific costing techniques in particular sectors and supply chain functions for different managerial purposes [3]. In doing so, the literature has also shown that the emphasis on particular techniques is due to their precedence and the panoply of their applications. In contrasting the aforementioned CAT with the Time-Driven Activity Based Costing (TDABC), -a derived technique from the ABC- its application is still at the infancy since the technique was developed early 2000s compared to ABC that was developed in 1988.

Despite the infancy stage, the applications of TDABC in healthcare are prominent and evolving rapidly [4]–[6]. However, its application in supply chain and operations management is still ambiguous. Consequently, the knowledge about the capabilities of the TDABC in a supply chain context is still unclear, and more research is needed to clarify its capability to assess the performance in supply chain and logistics function.

The present study seeks to contribute to the TDABC debate and provide an application of TDABC in the manufacturing context. Thus, the study aims to demonstrate the application in logistics function within a manufacturing context, to explore the technique's capability by assessing the suitability of the TDABC to assess the performance of the studied processes.

2. Literature about TDABC and its application in logistics

TDABC was developed to address the shortcoming of the ABC. Namely, resistance to change, time consumption for data gathering to feed ABC implementation, measurement errors, the lack of detail to capture some complexities, the lack of coordination between the ABC system in different departments, the difficulty in updating the system or bring any modification [7]. In doing so, TDABC presents several advantages compared to its predecessor throughout the literature. The derived advantages are focused around four axes: Implementation, maintenance, application environment and decision-making.

2.1 From an implementation perspective

Previous studies emphasised the simplicity, rapidity and affordability of the TDABC process as compared to ABC [7]–[9]. The first stage of TDABC implementation is simplified by eliminating the activity determination step required in ABC. TDABC does not require extensive interviews with employees to determine the activities incurred and the cost drivers that trigger these activities. The simplicity of the process is also reflected in the use of standard data as the basis for the calculations, which minimises the amount of data to gather [10] and reduces the time spent doing expensive interviews and surveys. In addition to standard data, the technique mainly uses time drivers as cost drivers and optimises the time spent deciding on the most appropriate cost driver [10]. Time drivers translate the characteristics that influence the duration time of a given activity or process. They can either be continuous variables such as the weight of a pallet, discrete variables (number of customers), or indicator variables. The latter can be represented by Booleans values (1or 0); for instance, 1 in the case of a new customer or 0 for an old customer [11]. Nevertheless, the time equations that integrate multiple time drivers can reflect the complexity and non-homogeneity of the activities without increasing the number of activities [11], [12]. In addition to the benefits presented from an implementation perspective, the process allows for dealing with accounting data without the need for prior experience in the financial and accounting field [12].

2.2 From a maintenance perspective

TDABC requires inexpensive maintenance [8]. The model's ability to integrate resource demands from different operations comes from adding more terms to the time equations, making it easier to reflect the new changes and maintain the model [13]. TDABC models do not require expensive software to process data nor consumes an extensive amount of time to present results. In contrast, ABC cannot run on basic spreadsheets when multiple activities are involved, resulting in many cost drivers, surpassing the capacity of spreadsheets [14]. Conversely, TDABC models generate results automatically and can be frequently run [15] Another advantage related to maintenance is the ease of incorporating a change of cost rates and updating them in the model, which would not require re-conducting interviews to update the system.

2.3 From an application perspective

TDABC applications covered healthcare, hospitality, financial services, libraries, manufacturing and logistics [16]–[20]. However only few applications have been reported in logistics. [12] reported several case studies in logistics companies (e.g. [11], [21]). The technique was implemented in a Belgian distribution centre to capture the complexity of logistics operations. The application of TDABC at the wholesale level reduced the number of activities from 330 under ABC to 106; as reported by [22], the traditional ABC misallocated 55% of the indirect costs. Another application of TDABC in a distribution centre was made by [10], that considered two capacity rates. The first is based on time and the other on kilometres. It provides an image of resource consumption by each product category and freight type (according to a radius). Early TDABC applications targeted medium and large logistics companies. The technique also explored its applicability in a Romanian distribution centre with complex operations covering sales order processing activities and the reception of goods [23]. Based on action research,[24] applied TDABC in a warehouse through regression analysis. They compare between transaction and duration cost drivers and a model integrating one single driver with multiple drivers. The second model was able to explain cost behaviour variability up to 50%, but the significance of the results is questionable. Distinctively from most TDABC articles that demonstrate the implementation of the technique, [25] show how the design of the technique can improve the operational performance of the activities studied. They did not specify the activities but rather focused on the participative approach (or not) of employees to determine time estimates and leadership style. Through a combined application of TDABC and the theory of constraints for a small-sized company in China; the logistics activities were also analysed. The combination allowed a more accurate cost estimation, taking into consideration the limitations and bottlenecks of the system [26], [27].

In parallel to the logistics applications, fewer applications were found for production/ manufacturing activities. Since the results of TDABC applications in manufacturing are debatable. [15], [27]–[30]. They highlight the increased complexity due to increased number of activities compared to logistics, or difficulty to determine the number of final product units processed each time due to high automation [29]. Despite the complexity a survey by [18] reported that TDABC applications were successful in the Jordanian industrial context, and its implementation has helped improve performance by reducing costs and improving profitability.

2.4 From a decision-making approach

The implementation of the TDABC contributed to improving managerial decision-making. Decisions related to resource allocation, product and service mix, and pricing were made more efficient, resulting in increased profitability [31]. The implementation allowed detecting inefficiencies and non-adding value activities, which facilitated defining the root cause of the problem [8]. For instance, process inefficiencies were detected through tracing of changeovers costs in production, packaging, picking, loading and delivering, [25] and the reduction of storage time in the warehouse [14]. Such a detailed process also allows for a performance assessment through the evaluation of capacity usage and quantification of idle capacity [8]. Furthermore, it enables the estimation of resource consumption and the re-engineering of the existing processes to improve the efficiency of processes and optimise the capacity usage and forecasting of costly resources [7], [32], [33]. As a control system, the technique compelled a compliance standard among employees [25]. The implementation helped decision making at the inter-organisational level. TDABC results were used for re-negotiations with business partners, leading to profitable solutions for both parties such a re-negotiation of freight rates and reduction of truck waiting times [14]. The technique can endorse future decisions through a what-if scenario based on cost, profit, time, and capacity by simulating a change in the customer's behaviour and predicting results [7]

4. TDABC simplified

The TDABC technique is based on the calculation of two main parameters: capacity cost rate and time equations. The first calculates the cost per time of supplying the capacity and capacity usage; the second describes the process based on the total time spent per each process by assigning resources costs to the activities and transactions performed. Detailed steps can be found in the stated literature.

4.1 Capacity cost rate

It represents the quotient of cost of capacity supplied by the practical capacity of resources supplied. Capacity cost rate is used to drive departmental resource costs to cost objects, by calculating the demand for resource capacity that cost objects need [7].

Capacity cost rate = $\frac{cost\ of\ capacity\ supplied}{practical\ capacity\ of\ resources\ supplied}$

4.2 Time equations

The TDABC literature emphasises the novelty of the technique in the elaboration of time equations, calculating the duration time of every activity based on its characteristics. The characteristics of the activity are referred to as time drivers. These characteristics affect the processing time by either augmenting or shortening the duration of the total activity [7] and could reflect the contextual factors affecting the operational performance. Each activity is affected by multiple characteristics, hence, multiple time drivers and variables.

The time equations translate the consumed time by an event in function of other activities and their time drivers, mathematically it can be expressed like the following

$$\mathrm{T} = \alpha + \sum_{i=0}^{n} AiXi$$

T– Time required for executing the event *E* based on Ai activities
α– Constant amount of time for activity *A*
Ai – Time consumed per unit of time driver 1
X_i – Time driver i
n – Number of drivers needed to run the activity

5 Case study

The case study company is a manufacturing company that operates in the automotive sector in Morocco. The company will be referred to as XYZ for confidentiality reasons. The activity of XYZ is dedicated to the sewing-cutting of car seat covers intended exclusively for export to Europe with a portion intended for the local OEM. The site is the Group's sixth plant dedicated to this activity in Europe /North Africa. To assess the capabilities of the technique to evaluate the performance, TDABC is applied to the logistics activities of the case study.

5.1 Logistics activities

The inbound logistics activities within XYZ can be summarised in the four main processes: the reception of goods, quality inspection, put-away, storage and picking. After the picking starts, come the related activities to production: cutting, sewing, foaming, and filling. If all quality tests are fulfilled, the finished products are ready for expedition. The detail of each process is shown in the process flow diagram in the appendix.

5.2 TDABC application

5.2.1 Capacity cost rate

Following the approach of [7], [34], the capacity cost rate of the main processes is calculated by dividing the total aggregated department costs over the total capacity supplied.

The cost of capacity supplied is calculated by summing the cost of all the resources used in the logistics department or process, including personnel, supervision, occupancy, equipment, and technology as shown in Table1.

Table 1: Total costs of logistics department

		Monthly cost	Yearly cost
Space cost	Rent/leasing	10000	120000
	Insurance	19000	228000
	Cleaning	8000	96000
	Maintenance cost	112187.87	1346254.5
Utility costs	Electricity cost	14427.84	173134.08
	Water	16633	199596
	Security	10000	120000
Direct labour costs	operators	75400	904800
	supervisors	21000	252000
	HSE wear	20000	240000
Indirect costs		56000	672000
Equipment cost (rented)	Stacker 1	13542	162504
	Forklift	11937	143244
	Counterbalance truck	10850	130200
	Stacker 2	5250	63000
	Stacker 3	3750	45000
Miscellaneous costs	communication (Phone +internet)	7000	84000
	Supplies (tape, stickers, paper)	2500	30000
Equipment cost (one-off)			
RFID reader	15000		
Zebra printer (RFID tag)	20000		
Printer	7000		
Depreciation of equipment			35285.85
Total warehousing costs in MAD		**427543.51**	**5165808.03**

To calculate the practical capacity, a nominal capacity is computed first. The nominal capacity at XYZ is defined by the total time available for employees to operate the work for inbound logistics activities (see table 2). In the logistics department, the work is executed over 24 hours in 6 days out of 7 per week. Consequently, operators' work is distributed over three shifts (morning, afternoon, and evening) of 8 hours each, where the number of operators changes.

Table 2: Number of resources for each process

Process	Morning shift	Afternoon shift	Night shift
Reception	4	4	1
Quality reception	2	2	2
Put-away	4	4	1
Picking	7	7	1

These resources are mainly the operators who conduct all the activities of reception, control quality, put-away/storage, and picking noting that the same resources who proceed with the reception activities proceed with the put-away.

Following the recommendations of [7] for the calculation of practical capacity, and after concerting with the managers, this capacity was estimated at 80% of the nominal capacity. The 20% accounts for the restroom and cigarette breaks as well as prayer time.

Based on the calculations (see appendix), the capacity cost rate is:

Capacity cost rate	1.54 MAD/min	92.7 MAD/h

5.2.2 Time equations

In order to develop the time equations of the four processes, the sub-activities of each process needed to be determined along with their characteristics. In fact, these characteristics affect processing times, inform the time drivers and shape the time equations. Based on process mapping and interviews with different staff, the time drivers of the main processes were defined and are presented in Table3.

Table 3: Time drivers for the logistics processes

Process	Time driver	
Reception	Type of product: component, textile (rolls) or chemical product N of missing documents	N of references scanned N of manifests N of pallets
Quality control	Type of supplier: new or problematic	Batch quantity/ number of boxes

Put-away	Type of product: component, textile or chemical product Type of handling: manual or machine-oriented	Bin location status: full or empty Availability of the stocking area operator
Picking	Type of demand: component, textile (Rolls) or Foam (chemical product)	Distance transported Type of handling

Another requirement to develop the time equations is the time estimate of the sub-activities. XYZ time measurements considered for TDABC were taken from the ERP systems and when not available instant time measurements were taken: the activities were stop watched. To increase confidence in time measurement, 30 time estimates were made for each sub-activity when possible. An estimation from the management was required when no measurement was possible. The time equations translate the occurrence of the activities and their time drivers as presented in Table 4.

Process	Time equations
Reception	$\mathbf{1+ 14.17+ 10.15\ X_4+ 90\ X_5+ 2.36\ X_8X_9+ 2.74*3\ X_6+ 1.15X_1X_{10}+ 0.66\ X_2X_{11}+ 0.63\ X_{12}\ X_{13} +1.63X_3\ X_{22} +3.87\ X_1X_{10}+ 1.04\ X_2X_{11} +0.12\ X_2X_{13} + 5\ X_7}$
Quality inspection	$\mathbf{1+ 2.41X_{14}\ (X_{23}X15X_1+ X_{24}X_{15}X_2) + 3.01\ X_1\ X_{14}\ X_{16} + 5.63\ X_2\ X_{14}\ X_{16} + 15*2\ X_{17}\ (X_1+X_2) +705\ X_{15}X_1+ 12\ X_{15}\ X_2 + 135\ X_1X_{15} + 10\ X_2X_{15} + 15}\ X_{15}$
Put-away	$\mathbf{5 + 1.51\ X_1X_{18}+ 5.17\ X_{25}X_1\ X_{10}+ 0.76X_2X_{19} + 1.02\ X_3X_{20} + 0.94\ X_1 +\alpha 3}$
Picking	$\mathbf{0.25+ 1\ X_1+ 1\ X_1 + 0.82\ X_2 + 0.22\ X_1 + 0.\ 22\ X_2 + 2.49\ X_1X_{21} + 0.86\ X_2X_{21}}$

Table 4: Time equations of the logistics processes

6. Findings

Following the development of the time equations for the macro processes and the calculation of the capacity cost rate, the total duration of the processes is calculated, and the cost of each process is then assessed. The model allows to assess the process durations based on different scenarios as shown in Table 5. Based on real data and what-if scenarios, the total duration of the process and the total cost will be compared.

Reception				
Scenario N	**S1**	**S2**	**S3**	**Average time of the process**

Scenario detail	No discrepancy is reported	Reception missing documents	reception with missing barcodes	
Total time in hours	**5.36 h**	**8.36**	**6.11**	**6.61**
Quality inspection				
	S4	**S5**	**S6**	**Average time of the process**
	No issue reported	when 6 references are faulty (without return)	when references are faulty & a new batch is expected	
Total time in hours	**1.51**	**13.42**	**157.67**	**57.53**
Put-away				
	S7	**S8**		**Average time of the process**
	No issue reported	When bin location is not available		
Total time in hours	**6.69**	**7.52**		**7.1**
Picking				
	S9	**S10**		**Average time of one off**
	One-off picking of 5 components	Picking of 2 textile rolls		
Total time in min	**31.12**	**14.83**		**22.98**

Table 5: Average process times based on different scenarios

6.1 Reception of goods process

Initially, the calculations apply for one truck delivering goods. The calculations allow the assessment of the efficiency of the logistics activities based on duration and cost KPIs. The total time that the logistics department needs to receive all the material from the truck and based on the calculation of the capacity cost rate, the cost of the activity is calculated.

In an ideal scenario, where no discrepancy is reported (S1), the total time for executing the reception of the goods received in double deck truck is obtained by numerical application of the coefficients in the reception of good equation. In that situation, the total time is estimated at 321.71 min, which is equal to 5.36 h. If the truck is received with missing documents (S2), the total time is then 8.36h, but if no discrepancy is reported but some references are missing their barcode the process duration is then 6.11h. Based on these three scenarios, the average reception process time is 6.61h.

According to the E-receiving software, a local software to monitor the performance times in the warehouse, this particular truck was received in 18 h 36 min. By applying the cost rate, the operation cost 1720.51 MAD instead of 612.75 MAD.

6.2 Quality inspection

In the present delivery, six suppliers raised quality issues, which means that the components they delivered needed to undergo a quality inspection. The six suppliers were responsible for delivering ten different components references. After testing the ten problematic references, four of them conformed to the quality norms, while the six others needed to be isolated and sorted. If after the inspection the references are conforming (S4), the process lasts for 1.51h. The faulty references needed to be isolated so the process average time in this scenario (S5) is 13.42h whereas after the sorting, XYZ is expecting a replacement batch (S6), the process time is equal to 157.67h. The average quality inspection based on S4, S5& S6 is 57.53 h. In terms of costs this process cost an average of 5333.34 MAD.

6.3 Put-away process

Based on previous data, putting away the 35 pallets with 30 different references, 130 textile rolls, two containers of chemical product and three pallets of textile rolls, 30 references of components will be 401.47 min or 6.69 h when no issue is reported (S7). However, the operation was not straightforward. The workers were faced with overstock and found themselves constrained to find space for five references that did not have a static bin location shelves and had to be returned to TRA, requiring an alternative solution. Consequently, the final time needed to complete the process was 452.43 minutes or 7.52 hours (S8), which in pecuniary terms, costs the company 648.9 MAD.

6.4 Picking

Regarding the picking process, a different example is taken since the process depends primordially on production demand. In this example, one operator feeds the production lines, using a virtual picking list constituted of 5 component references within a perimeter of 5 meters. Another operator is picking two textile rolls and transporting them to the same area. The picking operation takes an average of 22.98 minutes between the two components. Thus, the equivalent cost of the process for one operator is 35.39 MAD.

7. Summary of the results and conclusion

Through the application of TDABC, the present study aspires to assess the operational performance of the current configuration. The application of TDABC implied calculating the time equations and capacity cost rates for the main processes in the logistics department. The two main parameters that provided the foundation for the selection of the KPI were the activities duration and the process cost. Through a numerical application, which represents the reception of one truck, a first insight is given. **Error! Reference source not found.** 6 summarises the processes times based on one truck received and one picking order.

Table 6: Comparison of TDABC results for one truck with real values

Process	Calculated Duration (CD)	Real duration (RD)	Cost in MAD
Reception of raw material	6 h 36 min	18h 36 min	612.78 for CD 1720.51 for RD
Quality inspection	57h 31 min	-	5333.34
Put-away	7 h 06min	7h 32	658.63 for CD 696. 74 for RD
Picking	0 h 23min	14min	35.39

From the results, it seems that the quality process inspection is the lengthy process in the inbound logistics, that can last for days specially when components are not quality conforming and need to be isolated and sorted. The process is more lengthily when a new delivery is expected from the supplier to replace the infected batch. In contrast with the quality inspection, the picking process is the least time consuming and last for minutes. In cost terms, it translates as the least costly process. While the reception of goods and their put-away is relatively close. The real number for the put away are closely link to the calculated numbers however for the reception of goods a noticeable difference.

The results show a considerable discrepancy between the calculated process times and the real process times. Considering the same input, i.e., one truck with specified quantities of references and textile rolls to allow for comparison. The calculated values are the average of different scenarios however, the real-life scenario is a combination of these scenarios. The values shown by the E-receiving for the reception times varied from 8 to 24h span depending on the combination of the scenarios and a number of idiosyncrasies such as :

- Some manifests were absent from the check-list
- Response time of the concerned parties to contact supplier lasted more than the estimated time of management response

- Although the textile rolls were received with their barcoded labels, some labels were damaged during the transport while others were not readable through the RFID reader and needed new labels

While TDABC allows to account for different scenarios as seen in table5, the linear model disregards the interlink between the processes. For instance, the reception and quality inspection are dependent upon one another. Furthermore, the model does account for the parallelism of activities, the availability of resources and assumes a sequential order of activities. This illustrated in the following example. Considering that five trucks are received, we assume that the first processes duration will be multiplied by five resulting in large duration that do not reflect the reality. For instance, if the reception is taking up 5 hours for one truck, for the five trucks, it will result in 25 hours, assuming that all the resources are available and engaged in the reception of the material.
However, in a real context, not all trucks arrive at the same time. The peculiarity of one truck is not necessarily replicable to other trucks. For instance, Truck N2 had all documents conform, while truck N3 had several missing documents but carried no reference from the problematic suppliers which implies different process durations. Or the put-away of the truck N1 content was done in parallel with the reception of Truck N3. The linear approach would tend to overestimate or misestimate the process times.

Previous applications of TDABC emphasised that the model is successful in independent warehouses/ distribution centres, however in manufacturing context, the TDABC applications are divided between successful and unsuccessful applications [15], [29], [35]. This study shows that TDABC is well suited to model situations and processes with low variability and therefore is able to reflect closely the performance of these processes. However, for processes that encompass lot of change and diverse what-if scenarios due to the intricacy of the activities and the different time-drivers that affect the total durations, the model is less suited. In fact, the uncertainties and idiosyncrasies are not easily captured through the static application of the TDABC, hence the need for the dynamic version of TDABC that integrates into a discrete event simulation to reflect the real-life scenarios.

References

[1] H. I. Kulmala, J. Paranko, and E. Uusi-Rauva, “The role of cost management in network relationships,” *Int. J. Prod. Econ.*, vol. 79, no. 1, pp. 33–43, 2002.
[2] W. H. Tsai, H.-C. Chen, J.-Y. Liu, S.-P. Chen, and Y.-S. Shen, “Using activity-based costing

to evaluate capital investments for green manufacturing systems," *Int. J. Prod. Res.*, vol. 49, no. 24, pp. 7275–7292, 2011.

[3] S. Rahoui, A. Mahfouz, and A. Arisha, "Supply Chain Costing– a Systematic Literature Review," in *Logistics Research Network Conference Proceeding 2017-Southampton Solent University*, 2017, pp. 230–242.

[4] A. P. B. da S. Etges, C. A. Polanczyk, and R. D. Urman, "A standardized framework to evaluate the quality of studies using TDABC in healthcare: the TDABC in Healthcare Consortium Consensus Statement," *BMC Health Serv. Res.*, vol. 20, no. 1, 2020.

[5] A. P. B. da Silva Etges *et al.*, "An 8-step framework for implementing time-driven activity-based costing in healthcare studies," *Eur. J. Heal. Econ.*, vol. 20, no. 8, pp. 1133–1145, 2019.

[6] G. Keel, C. Savage, M. Rafiq, and P. Mazzocato, "Time-driven activity-based costing in health care: A systematic review of the literature," *Health Policy (New. York).*, vol. 121, no. 7, pp. 755–763, 2017.

[7] R. S. Kaplan and S. R. Anderson, *Time-driven activity-based costing: a simpler and more powerful path to higher profits*. 2007.

[8] B. G. Ardiansyah, B. Tjahjadi, and N. Soewarno, "Measuring customer profitability through time-driven activity-based costing: a case study at hotel x Jogjakarta," *SHS Web Conf.*, vol. 34, p. 08004, 2017.

[9] A. Reynolds, H. Fourie, and L. Erasmus, "A framework for time-driven activity-based costing implementation at small and medium enterprises," *South. African J. Entrep. Small Bus. Manag.*, vol. 10, no. 1, pp. 1–11, 2018.

[10] P. Afonso and A. Santana, "Application of the TDABC model in the logistics process using different capacity cost rates," *J. Ind. Eng. Manag.*, vol. 9, no. 5, pp. 1003–1019, 2016.

[11] W. Bruggeman, P. Everaert, S. R. Anderson, and Y. Levant, "Modeling Logistics Costs using Time-Driven ABC : A Case in a Distribution Company," *Concept. Pap. Case Study*, pp. 01–51, 2005.

[12] L. Siguenza-Guzman, A. Van den Abbeele, J. Vandewalle, H. Verhaaren, and D. Cattrysse, "Recent Evolutions in Costing Systems: A Literature Review of Time-Driven Activity-Based Costing," *Rev. Bus. Econ. Lit.*, vol. 58, no. 1, pp. 34–64, 2013.

[13] M. Todorović, "Organizational and Methodological Aspects of Time-Driven Activity Based Costing," pp. 203–217, 2016.

[14] S. Somapa, M. Cools, and W. Dullaert, "Unlocking the potential of time-driven activity-based costing for small logistics companies," *Int. J. Logist. Res. Appl.*, vol. 15, no. 5, pp. 303–322, 2012.

[15] F. Öker and H. Adıgüzel, "Time-Driven Activity-Based Costing: An Implementation in a Manufacturing Company," *J. Corp. Account. Financ.*, vol. 22, no. 1, pp. 39–56, 2016.

[16] P. Yonpae and J. Sungwoo, "Time-driven activity-based costing systems for marketing decisions," vol. 14, no. 14, pp. 191–207, 2019.

[17] M. Bagherpour, "Risky Time Driven Activity Based Costing in a Medical Center: A Development, Implementation and Simulation based Optimization Approach," *J. Account. Manag.*, vol. 5, no. 2, pp. 47–61, 2015.

[18] N. B. Al-Halabi and Y. M. Al-Mnadheh, "The Impact of Applying Time Driven Activity-Based Costing on Improving the Efficiency of Performance in Jordanian Industrial Corporations: A Survey Study," *Int. J. Econ. Financ.*, vol. 9, no. 12, p. 24, 2017.

[19] E. Pernot, F. Roodhooft, and A. Van den Abbeele, "Time-Driven Activity-Based Costing for Inter-Library Services: A Case Study in a University," *J. Acad. Librariansh.*, vol. 33, no. 5, pp. 551–560, 2007.

[20] J. Gregório, G. Russo, and L. V. Lapão, "Pharmaceutical services cost analysis using time-driven activity-based costing: A contribution to improve community pharmacies' management," *Res. Soc. Adm. Pharm.*, vol. 12, no. 3, pp. 475–485, 2016.

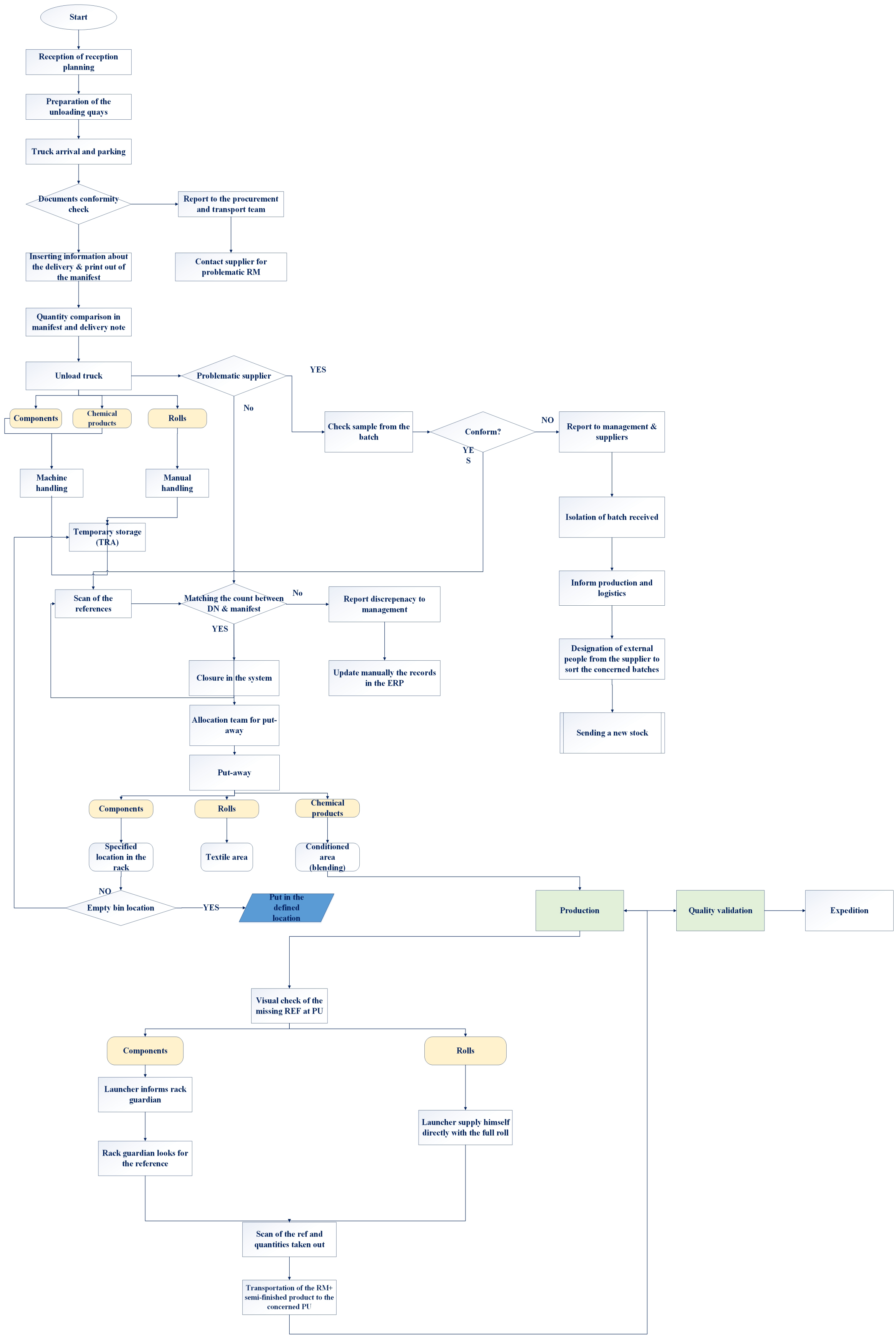
[21] M. Gervais, Y. Levant, and C. Ducrocq, "Time-Driven Activity-Based Costing (TDABC): An Initial Appraisal through a Longitudinal Case Study," *J. Appl. Manag. Account. Res.*, vol. 8, no. 2, 2010.

[22] J. Bryon, K; Everaert, P; Lauwers, L; Van Meense, "Time-driven activity-based costing for supporting sustainability decisions in pig production," *Inst. voor Landbouw en Viss. Eenheid*

Landbouw Maatsch., no. June 2014, pp. 1–29, 2008.
[23] A. A. Diaconeasa, N. Manea, and S. Oprea, "Modeling Costs Using Time Driven ABC Method in Logistic Activities," *Supply Chain Manag. J.*, no. 1, pp. 88–97, 2010.
[24] M. Varila, M. Seppänen, and P. Suomala, "Detailed cost modelling: a case study in warehouse logistics," *Int. J. Phys. Distrib. Logist. Manag.*, vol. 37, no. 3, pp. 184–200, 2007.
[25] S. Hoozée and W. Bruggeman, "Identifying operational improvements during the design process of a time-driven ABC system: The role of collective worker participation and leadership style," *Manag. Account. Res.*, vol. 21, no. 3, pp. 185–198, 2010.
[26] X. Zhang and H. Yi, "The analysis of logistics cost based on time-driven ABC and TOC," *Proc. 2008 IEEE Int. Conf. Serv. Oper. Logist. Informatics, IEEE/SOLI 2008*, vol. 2, pp. 1631–1635, 2008.
[27] S. Y. Huang, H. J. Chen, A. A. Chiu, and C. P. Chen, "The application of the theory of constraints and activity-based costing to business excellence: The case of automotive electronics manufacture firms," *Total Qual. Manag. Bus. Excell.*, vol. 25, no. 5–6, pp. 532–545, 2014.
[28] H. Korpunen, S. Mochan, and J. Uusitalo, "An Activity-Based Costing Method for Sawmilling," *For. Prod. J.*, vol. 60, no. 10, pp. 420–431, 2010.
[29] R. Silva Barros and A. M. Dias Simões da Costa Ferreira, "Time-driven activity-based costing: designing a model in portuguese production," *Qual. Res. Account. Manag. Manag.*, vol. 14, no. 1, pp. 2–20, 2017.
[30] A. . Anderson and A. van Der Merwe, "Time-Driven Activity-Based Costing Related To Digital Twinning In Additive Manufacturing," *South African J. Ind. Eng.*, vol. 32, no. 1, pp. 37–43, 2021.
[31] R. S. Kaplan *et al.*, "Using time-driven activity-based costing to identify value improvement opportunities in healthcare," *J. Healthc. Manag.*, vol. 59, no. 6, pp. 399–412, 2014.
[32] P. Everaert, W. Bruggeman, G. Sarens, S. R. Anderson, and Y. Levant, "Cost modeling in logistics using time-driven ABC," *Int. J. Phys. Distrib. Logist. Manag.*, vol. 38, no. 3, pp. 172–191, 2008.
[33] M. Namazi, "Time-driven activity-based costing: Theory, applications and limitations.," *Iran. J. Manag. Stud.*, vol. 9, no. 3, pp. 457–482, 2016.
[34] R. S. Kaplan and S. R. ; Anderson, "Time-driven activity-based costing," *Harv. Bus. Rev.*, vol. 82, no. 11, pp. 131–138, 2004.
[35] M. Wouters and J. Stecher, "Development of real-time product cost measurement: A case study in a medium-sized manufacturing company," *Int. J. Prod. Econ.*, vol. 183, no. March 2015, pp. 235–244, 2017.

Appendix

1-Logistics process flow


Start
Reception of reception planning
Preparation of the unloading quays
Truck arrival and parking
Documents conformity check
Report to the procurement and transport team
Contact supplier for problematic RM
Inserting information about the delivery & print out of the manifest
Quantity comparison in manifest and delivery note
Unload truck
Problematic supplier
YES
No
Components
Chemical products
Rolls
Check sample from the batch
Conform?
NO
YES
Report to management & suppliers
Machine handling
Manual handling
Isolation of batch received
Temporary storage (TRA)
Inform production and logistics
Scan of the references
Matching the count between DN & manifest
No
Report discrepenacy to management
YES
Designation of external people from the supplier to sort the concerned batches
Closure in the system
Update manually the records in the ERP
Sending a new stock
Allocation team for put-away
Put-away
Components
Rolls
Chemical products
Specified location in the rack
Textile area
Conditioned area (blending)
NO
Empty bin location
YES
Put in the defined location
Production
Quality validation
Expedition
Visual check of the missing REF at PU
Components
Rolls
Launcher informs rack guardian
Launcher supply himself directly with the full roll
Rack guardian looks for the reference
Scan of the ref and quantities taken out
Transportation of the RM+ semi-finished product to the concerned PU

2- Practical capacity and capacity cost rate

Consequently, operator work is distributed over three shifts (morning, afternoon, and evening) of 8 hours each, where the number of operators changes. Nominal capacity was calculated by multiplying daily working hours by the total number of employees in each process and the number of working days per year.

Operators	morning shift	afternoon shift	night shift
Operators (Reception & Put-away)	32	32	8
Quality reception	16	16	8
Picking	56	48	16
Total worked hours/day	216		
Total worked days	300		
Nominal capacity	76032		
Practical capacity in hours	60825		
Practical capacity in min	3649536		
Capacity cost rate	1.54 MAD/min	92.7 MAD/h	

3- Variables explanation of the time equations

Where:

X_1: 1 if it's a component, 0 otherwise. X_2: 1 if it's a textile roll, 0 otherwise. X_3: 1 if it's a chemical product, 0 otherwise. X_4:1 if documents are conform, 0 otherwise X_5: report to the management X_6:1 if truck if double-deck, 0 otherwise X_7:1 if the textile roll is coming with missing barcode X_8: number of lines in each manifest	X_9: number of manifests per truck X_{10}: number of pallets (component) X_{11}: number of rolls pallet X_{12}: 1 if rolls are handled manually X_{13}: number of textile rolls to be handled manually Ai, Bi, Ci,… represent the average values of the conducted activity i= 1, 2,3,4 : the number of the process	X_{16}: duration to check sample from the batch X_{17}: 1 if sample is not conform, 0 otherwise X_{23}: the number of problematic components X_{24}: the number of problematic roll

	X_{14}: 1 if the supplier is problematic, 0 otherwise X_{15}: number/ quantity of the components in the batch	

4- Numerical application of Reception Equation

	Reception	Average times	Average values	Coefficient	Corresponding variable
R1	Truck arrival+ parking	00:14:10	14.17	1	-
R2	Checking conformity of documents + sorting (separate invoices/BL)	00:10:09	10.15	1	X4
R3	Introducing information and print out of the manifest	00:02:21	2.36	Number of manifests	X9
R4	Response time when discrepancy is reported	01:30:00	90	90	X5
R5	Unloading of one pallet (components)	00:01:09	1.158	N of pallets	X10
R6	Unloading of rolls manually (chariot)	00:00:38	0.63	N of rolls	X13
R7	Unload of one pallet of rolls	00:00:40	0.66	N of rolls pallets	X11
R8	Unmounting double deck	00:02:44	2.74	3	X6
R9	Unload of chemical product	00:01:38	1.62	N of chemical containers	X20
R10	Scan of labels 1 palette (components)	00:03:53	3.88	N of components	X18
R11	Scan of rolls	00:00:07	0.12	N of rolls	X13

A direct numerical application of a real case situation, where a received truck had the following data is as follows:

Variable	Description	Value
X1	1 if it's a component, 0 otherwise	1
X2	1 if it's a textile roll, 0 otherwise	1
X3	1 if it's a chemical product, 0 otherwise	1
X4	1 if documents are conform, 0 otherwise	0
X5	1 if report to the management	0
X6	1 if truck if double-deck, 0 otherwise	1
X7	1 if the textile roll is coming with missing barcode	0
X8	Number of lines in each manifest	8-20

X9	Number of manifest per truck	11
X10	number of pallets (component)	35
X11	Number of roll pallets	3
X12	1 if rolls are handled manually	1
X13	Number of textile rolls to be handled manually	130
X20	Number of chemical product containers	2

Table 2: Variable values of the RE