5-2014

Time-Driven Activity-Based Costing for Healthcare Provider Supply Chain Processes

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A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Industrial Engineering

by

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Texas A&M University
Bachelor of Science in Industrial and Systems Engineering, 2011

May 2014
University of Arkansas

This thesis is approved for recommendation to the Graduate Council.

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ABSTRACT

In a time when healthcare costs continue to rise, nearly a third of hospital operating expenses are related to supplies, and the healthcare supply chain is complex, it is pertinent for healthcare providers to have a clear understanding of their healthcare supply chain process costs. Having a clear picture into how these costs are driven and where opportunities for cost reductions exist can support supply chain efficiencies. In this research, we develop a Time-Driven Activity-Based Costing (TDABC) supply chain cost management tool for healthcare providers. A TDABC management system can provide healthcare providers with valuable product and process supply chain cost information by investigating logistics activities, resource consumption, and time drivers. Based on prior expertise, existing literature, and a field study conducted with a 200-bed, not-for-profit hospital, a healthcare provider supply chain (HPSC) TDABC approach and supporting spreadsheet-based tool were developed to support cost measurement and management within the HPSC.

ACKNOWLEDGEMENTS

I would first like to thank my family for their unconditional love and support not only for the last 2 years but my whole life. To my dad for always encouraging me to move forward and "not let the turkeys get me down." Thank you dad for always being a phone call away and allowing me to vent when it was needed. También dedico este tesis para mi mama que me a enseñado que siempre debemos de reír y ser humildes. Gracias mama por tu honestidad, amor, y abrazos. For my brother who honestly is the best person I know and the reason I work so hard at everything I do. Thank you Miguel for your unconditional love, for calling me out when I am being crazy, and for being the best brother anybody could possibly wish for. Also the rest of my family and friends who have shaped me into what I am today, which hopefully is a kind and giving person.

Lastly I would like to thank all the faculty and staff of the Industrial Engineering Department at the U of A. Thank you guys for a wonderful two years and making the move away from Texas that much more bearable. You guys are full of love and support and I couldn't have asked for a better experience.

DEDICATION

I would like to dedicate this thesis to my family who have inspired and motivated me to follow my passions and be a beacon of God's light to others, you guys mean everything to me. Thank you for always believing in me, even when I didn't believe in myself.

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1 INTRODUCTION

Between 1950 and 2011, the United States (U.S.) GDP per capita grew an average of two percent per year while U.S. healthcare expenditures per capita grew more than four percent per year (Fuchs, 2013). In 2011, the healthcare expenditures comprised of nearly eighteen percent of the U.S. GDP(Fuchs, 2013) and it is projected to increase to nineteen percent by 2019 (Centers for Medicare and Medicaid Services, 2010). Currently, hospitals in the U.S. are challenged with successfully delivering quality healthcare under an environment of increasing costs and uncertain revenue. It has been recently reported that supply chain (SC) operations consume forty percent of a healthcare provider's total expenses (Darling and Wise, 2010). Improvement in healthcare provider supply chain operations can build system efficiency and help reduce healthcare delivery costs. Approximately five to fifteen percent savings in supply chain costs can equate to a one to three percent increase in a hospital's operating margin (Online Healthcare Marketplace, 2001). Improving supply chain operations for healthcare providers requires efficient and accurate cost management tools to measure and evaluate healthcare provider supply chain (HPSC) costs and identify potential areas of improvement.

Accurate costing is needed in healthcare provider supply chains because the environment in which they operate is dynamic and complex. Due to operational complexity, there is a general lack of visibility throughout the supply chain network and supply chain managers are challenged to understand how costs are being distributed. Without this visibility, supply chain managers misinterpret their costs and are unable to link costs to process improvements which inhibits their ability to make systemic and sustainable cost reductions (Kaplan and Porter, 2011). An accurate HPSC cost management tool can help managers understand their consumption of resources across supply chain activities, which leads to an increase in visibility. This visibility supports SC efficiency and cost savings through the identification of opportunities for improvement among the HPSC activities.

Activity based costing (ABC) is a cost management tool that increases visibility of costs and enables managers to make better informed cost-related decisions. ABC began in the manufacturing industry where companies needed a way to correctly measure the indirect cost of their products (Johnson, 1992). To measure the cost of resource consumption associated with operational activities, ABC identifies resources and their cost drivers and traces costs back to individual activities. Today, ABC has been applied within many industries including healthcare and logistics. Introduced by Kaplan and Anderson (2004), time-driven activity based costing (TDABC) is a cost management tool that has been found to capture system complexity such as that found in HPSCs. TDABC uses time equations to calculate the cost of each activity and makes maintenance of the cost model less tedious than traditional ABC. In the dynamic healthcare industry, this is a valuable feature in implementing an accurate costing system.

In this research, we develop a TDABC supply chain cost management tool for healthcare providers. A TDABC management system can provide healthcare providers with valuable product and process supply chain cost information by investigating logistics activities, resource consumption, and time drivers. Based on prior expertise, existing literature, and field study analysis, a HPSC TDABC approach and supporting spreadsheet-based tool were developed to support cost measurement and management within the HPSC.

1.1 Research Motivation

In an environment of increasing healthcare costs, an estimated twenty-five to thirty percent of a hospital's total operating expenses are supply costs (Neumann, 2003). The need to reduce costs is increasingly becoming a priority for hospitals. Increasing costs creates pressure to streamline operations and optimize resources within healthcare provider organizations. Today's hospital environments are characterized by higher indirect or overhead costs, increased complexity in product and service development and distribution, increased competition, and more advanced information technologies. Healthcare providers are in need of a cost management system that provides supply chain costing information by investigating logistics business activities, resource consumption, and time drivers.

1.2 Research Objective

The primary objective of this research is to develop a HPSC TDABC system and associated spreadsheet-based supply chain costing tool that will enable healthcare providers to accurately measure the cost of their supply chain process operations, analyze their SC cost behavior, and identify potential areas for SC process improvement. To develop and validate our HPSC TDABC approach, we conducted a field study with a 200-bed, not-for-profit hospital with a level III trauma center based in the Mid-West.

Our research objective was achieved through the completion of four major tasks: 1) review current literature on ABC in supply chain and healthcare systems, 2) develop our HPSC TDABC approach, 3) conduct a field study with our healthcare provider partner, and 4) develop a generalizable spreadsheet-based tool to help other healthcare providers develop a TDABC model of their supply chain process operations.

1.3 Research Contributions

This research contributes a HPSC TDABC methodology and tool to measure costs associated with HPSC process operations. Our HPSC TDABC methodology enables the implementation of TDABC within a healthcare provider's supply chain to measure cost behavior throughout their logistics activities and obtain accurate cost information to support SC process improvements. Our HPSC TDABC methodology is expected to provide healthcare providers with valuable product and process supply chain costing information by investigating logistics business activities, resource consumption, and cost drivers.

2 LITERATURE REVIEW

2.1 Activity-Based Costing

Activity-based costing (ABC) has two independent non-academic beginnings. In the early 1960s General Electric (GE), with the help of their finance and control people, sought to correctly manage indirect costs (Johnson, 1992). The second path, completely independent from GE, began in the 1970s and early 1980s by various companies and consultants who sought to "improve the quality of product cost information" (Johnson, 1992). Traditional ABC became largely possible due to advances in technology. In the 1970s, the advances of low-cost microchip technologies enabled companies to collect and organize vast amounts of information (Johnson, 1992). These companies were now able to sort cost information, use it to trace costs back to products, and make informed management decisions. In the late 1980s, the academic world formalized ABC into what it is today. Robin Cooper (1988-1989) originally codified the ABC design in a four part series in the Journal of Cost Management depicting the activity-based costing theory and its practical benefits. In 1990, Cooper described the ABC implementation process. Other ABC pioneers include H. Thomas Johnson and Robert S. Kaplan (1987) who wrote "Relevance Lost: The Rise and Fall of Management Accounting."

ABC started as a tool used primarily in the manufacturing industry and has expanded to other industries including healthcare and logistics. A literature search was conducted as part of this research and identified more than 600 related articles, which were narrowed to fifty-one articles that are directly related to ABC in healthcare, supply chain, or the healthcare supply chain. The primary purpose of the literature review was to support development of an activity-based supply chain costing methodology for healthcare providers. Of these fifty-one articles, thirty-one articles describe methodologies that could contribute to the development of our HPSC TDABC model and are the focus of our literature review. The thirty-one selected papers are categorized as shown in Figure 1. Most articles studied supply chain operations and focused on providing insights for ABC through literature reviews. These articles mainly presented their ABC methodology and discussed its challenges. Those articles which applied ABC in healthcare focused more on ABC as a managerial/ decision tool. Only one article (Federowicz, et al., 2010) provided insights in applying ABC and discussed ABC as a healthcare managerial/decision tool. None of the articles contained all categories of interest. The papers in the ABC Application/Literature Review categories were most useful in developing our HPSC TDABC methodology. Each category provided evidence that applying ABC in the healthcare supply chain adds value to supply chain managers.

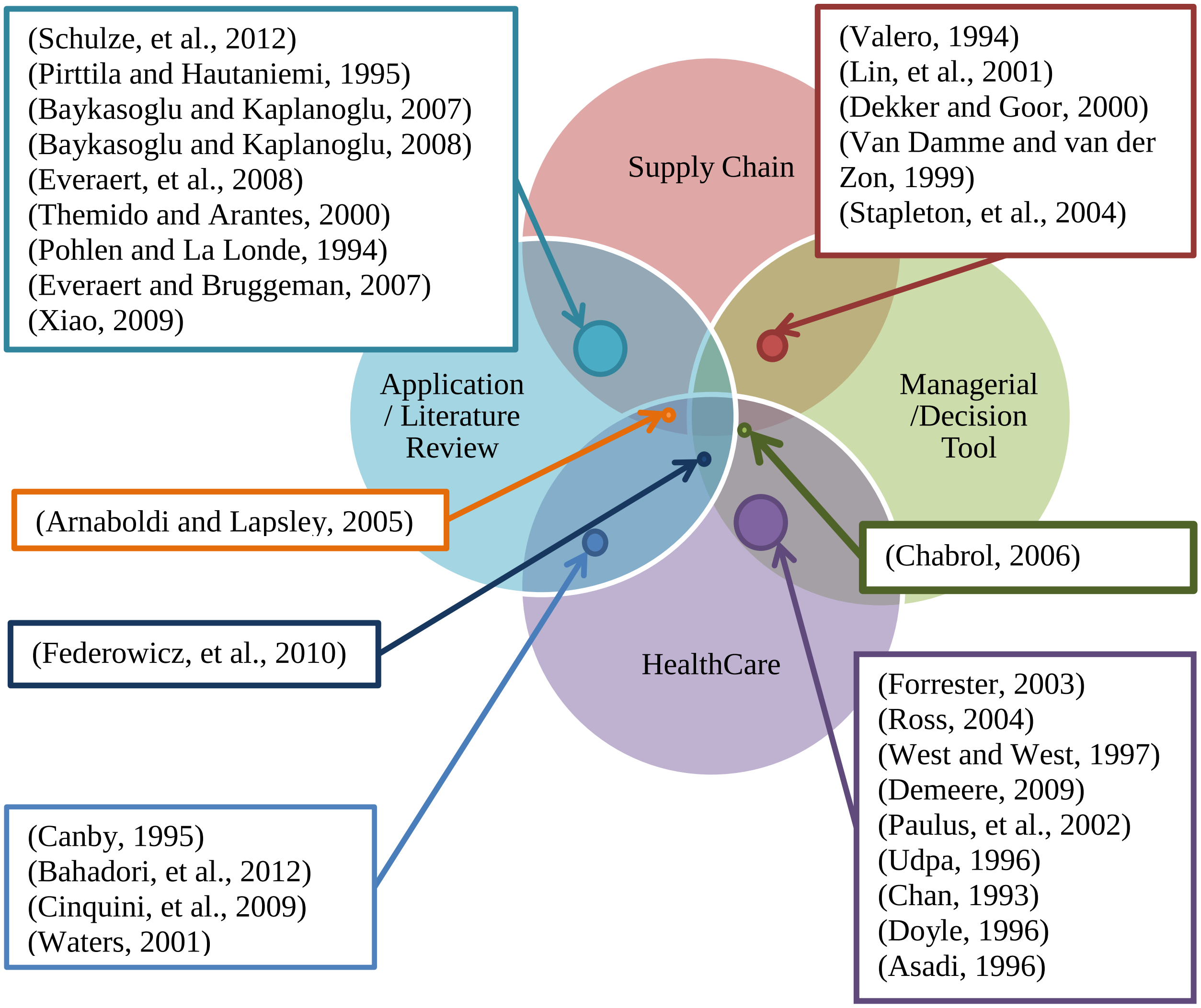

Figure 1. ABC Subject of Study and Purpose

2.1.1 ABC in Healthcare

Healthcare provides a highly customized service (Paulus, et al., 2002). There are two major components in a healthcare system, medical and financial. What makes healthcare unique to other industries is that the medical side does not regard cost as the main driver in the decision making process; while accountants do not have sufficient understanding of medical processes and personnel (Ross, 2004). The lack of coordination between the two components leads to poor cost awareness. In the 1980s and 1990s, the introduction of reimbursement constraints by the federal government increased the awareness and urgency for the providers to be more cost conscious (Ross, 2004; West and West, 1997). Unfortunately, standard accounting systems do not capture the true costs of healthcare services because there is much variability and complexity (Ross, 2004). ABC can provide accurate and relevant information, which assists healthcare systems in providing care, guiding financial management, and pursuing organization improvement (Ross, 2004).

Many HC providers use traditional volume-based costing methods when allocating and understanding cost behavior. However, overhead costs in a service industry, like healthcare, are not generally correctly allocated by volume due to the variability in services. ABC takes a system view and break processes down into activities, which can facilitate in the identification of the value-adding activities and can help hospitals recognize their inefficiencies. Many authors have concluded that ABC can aid in decision support for reengineering healthcare systems as well as function as a cost comparison tool (Bahadori, et al., 2012; Paulus, et al., 2002; Forrester, 2003; Arnaboldi and Lapsley, 2005; Cinquini, et al., 2009).

Our literature review found that articles applying ABC in healthcare often have a narrow scope (Cinquini, et al., 2009; Udpa, 1996; Arnaboldi and Lapsley, 2005). Examples include a dialysis clinic (West and West, 1997), emergency department service (Forrester, 2003; Ross, 2004; Glick, 2000), X-ray process (Canby, 1995), surgery in a hospital (Lin, et al., 2007), and hospital blood transfusion process (Arnaboldi and Lapsley, 2005) as shown in Figure 2. Each of these articles discovered challenges when applying ABC. As the complexity increased, the scope grew smaller in order to accurately implement ABC to the system. For example, blood transfusions made up seven percent of healthcare articles in our literature review and only applied ABC to two types of services (West and West, 1997). They were able to identify activities and resources at the highest detail possible. However, in a more complex systems like the emergency department (15%), articles examined hypothetical cases (Ross, 2004) or applied ABC at a high level (Forrester, 2003). With an increase in complexity, applying ABC in healthcare is a challenging task (Arnaboldi and Lapsley, 2005). The majority of the ABC healthcare articles did not focus on supply chain process operations. One exception was Arnaboldi and Lapsley's 2005 study of a United Kingdom blood transfusion clinic, which included the entire organization from manufacturing to final delivery.

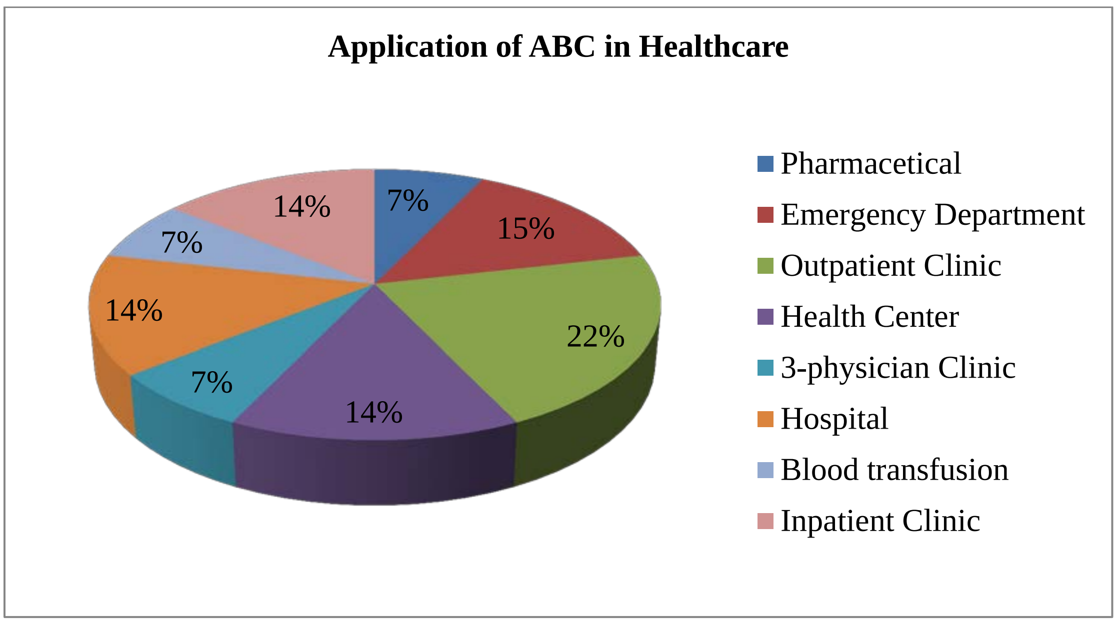

Figure 2. Application of ABC in Healthcare

2.1.2 ABC in Supply Chain

Activity based costing in supply chains has been widely studied across multiple phases of the supply chain. High supply chain operations cost used to be a necessary evil; now many industries have discovered that SC costs can be reduced and used as a competitive advantage (Lin, et al., 2001). ABC has become a popular tool in supply chain costing (Schulze, et al., 2012) and has helped supply chain managers gain more accurate cost information and make informed decisions regarding their supply chain processes (Schulze, et al., 2012; Dekker and Goor, 2000). In tracing costs and taking a closer look into SC processes, supply chain managers can observe which resources are being unnecessarily wasted and where improvements can be made to reduce logistics costs and inefficiencies (Stapleton, et al., 2004). To capture the true cost of a supply chain process, ABC identifies costs of resources and is able to trace back to the cost of a process (Lin, et al., 2001). This facilitates making improvements in the supply chain because ABC enables supply chain managers to see the distribution of supply chain process costs more clearly.

Figure 3 illustrates a closer look at the distribution of the selected ABC articles that focused on supply chain industries. The majority of the papers (63%) applied ABC in Wholesale/Distribution operations, while twenty-five percent studied ABC implementation in Third-Party Logistics organizations.

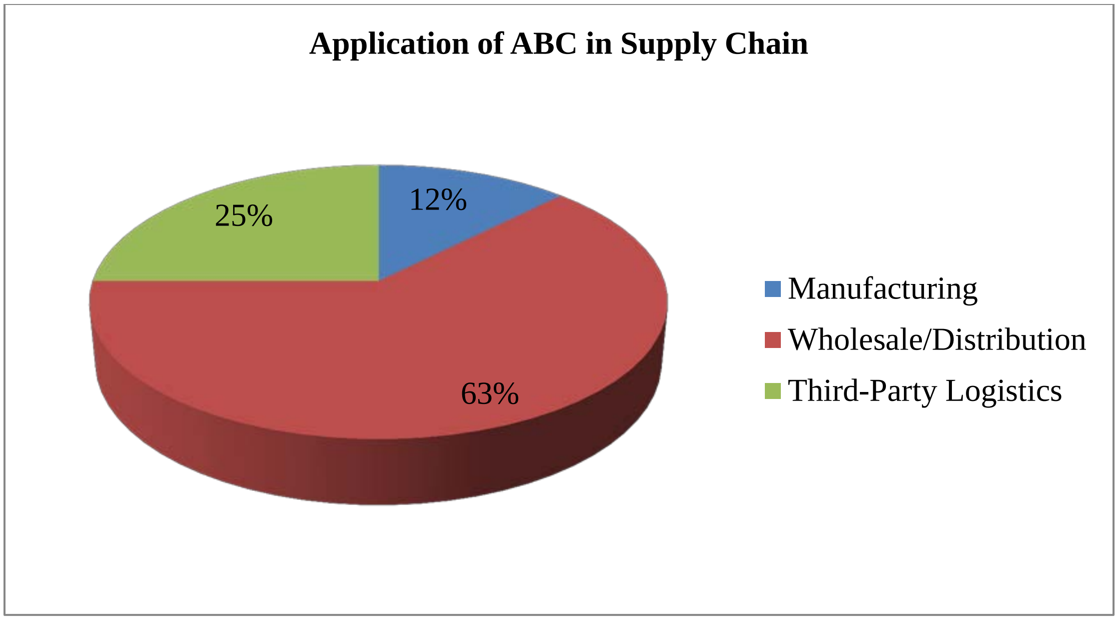

Figure 3. Application of ABC in Supply Chain

2.1.3 ABC in Healthcare and Supply Chain

Research in ABC of the healthcare supply chain is limited. In our 2012–2013 literature search of Ebsco, Proquest, and Web of Knowledge databases, 4630 articles were found on activity-based costing, and 624 selected articles met our specific criteria including topics in healthcare and/or supply chain, inclusion of case study and data, and inclusion of ABC methodology. Only four articles considered supply chain operations within the healthcare industry in their ABC implementation (Landry and Philippe, 2004; Arnaboldi and Lapsley, 2005; Udpa, 1996; Chabrol, 2006).

A true understanding of healthcare supply chain processes and activities is needed to successfully implement ABC (Landry and Philippe, 2004). Getting all levels of the supply chain to participate in the implementation of ABC poses a major challenge (Arnaboldi and Lapsley, 2005). Obtaining the necessary information to implement ABC requires careful coordination and a diverse team to identify HCSC activities (Udpa, 1996). It may not be feasible to implement ABC to supply chain operations because of inconsistent accounting data (Waters, 2001). If inconsistent, additional data collection and resources are needed, which is time consuming and expensive. ABC is not a quick fix; it requires support and cooperation not only from upper management but all functional areas involved in the healthcare supply chain (Udpa, 1996).

The literature agrees that ABC is an appropriate costing method for supply chain systems (Landry and Philippe, 2004; Chabrol, 2006; Waters, 2001; Arnaboldi and Lapsley, 2005). The supply chain is cross functional with multiple departments involved with various functions which makes it complex to track processes. ABC is an appropriate healthcare SC costing method due to its ability to capture complexity and breakdown the process (Chabrol, 2006). One advantage of ABC is that it provides the organization a better view of its healthcare supply chain. With this new perspective, the organization gains better insight into costs (Landry and Philippe, 2004). According to Landry and Philippe (2004, p. 28), this can provide momentum for “supply chain simulation and reengineering exercises to help improve costs and focus on areas where the greatest gain can be achieved.”

2.2 Time-Driven Activity-Based Costing

Managers trying to implement ABC in complex systems found that applying and maintaining the most accurate information in the ABC model was consuming large quantities of limited resources, and a costing model that captured system complexity and was sustainable when processes or cost changes occurred was needed (Kaplan and Anderson, 2004). Kaplan and Anderson (2004), the founding pioneers of ABC, found that ABC was met with a lot of challenges including accuracy in capturing the complexity of operations, implementation, and maintenance. While ABC was tracing the costs correctly, the estimates themselves did not correctly reflect the true cost. Specifically, they found that interviewing employees and asking for their percentage of time spent completing an activity was not always accurate (Kaplan and Anderson, 2004).

In response, Kaplan and Anderson (2004) developed time-driven activity-based costing (TDABC) to enable ABC to be easier to implement while still capturing system complexity. TDABC uses unit costs, time estimates, and time equations to facilitate in the implementation and upkeep of an ABC model. Table 1 describes Kaplan and Anderson's TDABC methodology (2004). Four directly relevant TDABC articles were found during our literature search, which address healthcare (Demeere, 2009), a logistics wholesaler company (Everaert, et al., 2008), an inter-firm supply chain (Schulze, et al., 2011), and an introduction to TDABC model (Everaert and Bruggeman, 2007). The primary functional difference in TDABC compared to traditional ABC is the use of unit costs and time equations.

Table 1: TDABC Methodology (Everaert, et al., 2008)

Time-Driven Activity Based Costing Methodology	
Step 1	Identify the various resource groups
Step 2	Estimate the total cost of each resource group
Step 3	Estimate the practical capacity of each resource group
Step 4	Calculate the unit cost of each resource group by dividing the total cost of the resource group by the practical capacity
Step 5	Determine the time estimation for each event, based upon the time equation for the activity and the characteristics of the event
Step 6	Multiply the unit cost of each resource group by the time estimate for the event
Step 7	Calculate total cost of the event by taking the sum of each time equation

Unit cost is the dollar amount each resource in the model is worth for each time unit selected. Unit costs are calculated by obtaining the total cost of resources and dividing it by the practical capacity. Practical capacity is the number of available resource hours. Unit costs help update the TDABC model more efficiently. In traditional ABC, the ABC model has to be completely revised every time there is a change in the resources (Everaert and Bruggeman, 2007). TDABC allows companies to use a spreadsheet tool to update the costing model (Kaplan and Anderson, 2004; Everaert and Bruggeman, 2007). Using practical capacity gives the model a more accurate estimate of the resource capacity and alleviates the need to ensure the percentage of time employees spent completing activities totaled to one hundred percent (Kaplan and Anderson, 2004).

One other main distinction of TDABC compared to ABC is the use of time equations. TDABC time equations allow managers to use multiple drivers for each activity as is often the case in complex systems (Schulze, et al., 2012; Everaert, et al., 2008). For each activity, the time required for the resources to perform these activities needs to be recorded. This is a change to finding the percentage of time each resource spends on an activity in traditional ABC.

Based on our literature review, we believe TDABC is an appropriate method for developing a healthcare provider supply chain costing tool. This is because TDABC is suitable for complex systems, such as a healthcare provider environment, and its data collection and maintenance approach is more practical than traditional ABC. Figure 4 shows a diagram of articles that use ABC or TDABC and include a case study and/or have actual costing data available. Articles that have case studies and data available are typically more detailed in their methodologies. This was useful when initially exploring which type of methodology would be appropriate in HPSC costing. Ultimately based on the methodology comparisons, TDABC was found to be the most appropriate costing method to develop for HPSC cost management. Only four of the articles used TDABC, and two of these include a case study with actual data. The Everaert (2008) and Demeere (2009) articles most closely resembled the complexity of the research scope.

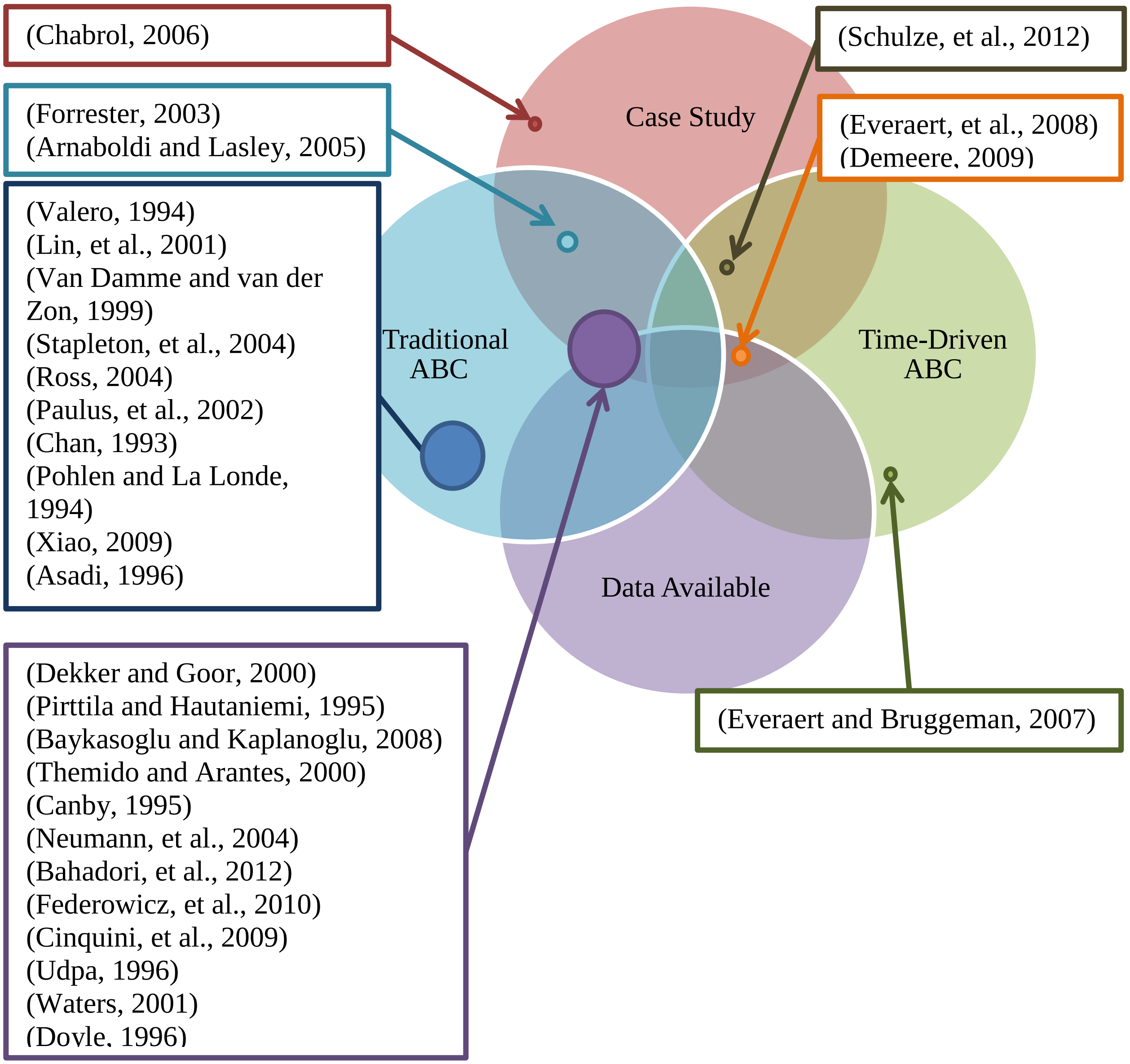

Figure 4. Comparison and Contrast of Traditional vs. Time-Driven ABC

To develop our HPSC TDABC methodology, multiple methodologies found in the literature review were studied and compared. ABC and TDABC emphasize the need for process mapping when applying these costing methods to complex systems. Process maps are created with the help of a team of employees who have extensive knowledge of the system. This knowledge is essential in creating process maps of the system to identify activities and resources (Canby, 1995; Cinquini, et al., 2009; Arnaboldi and Lapsley, 2005; Udpa, 1996; Asadi, 1996; Baykasoglu and Kaplanoglu, 2008; Pohlen and La Londe, 1994). However, not all of the reviewed articles stated the need for process maps; many jumped right into identifying activities and resources (Paulus, et al., 2002; Waters, 2001; Asadi, 1996; Ross, 2004; Chan, 1993). In complex systems, we believe creating process maps is an important step to identifying activities and resources, and defining the scope of the costing project.

The next step in the ABC/TDABC methodology is to identify activities, resources and drivers. Some reviewed articles did not provide details of this step (Pohlen and La Londe, 1994; Asadi, 1996; Ross, 2004; Chan, 1993), while others specified an approach such as interviewing employees to obtain necessary information (Cinquini, et al., 2009; Arnaboldi and Lapsley, 2005; Paulus, et al., 2002; Udpa, 1996; Waters, 2001). Paulus, et al. (2002) makes four suggestions on how to identify activities and drivers: "(1) ask the managers, (2) ask the employees, (3) ask the employees to register required information, and (4) observation of all employees by the outside," Certainly all four are possible but observation provides more accurate data than the other three options (Paulus, et al., 2002).

In TDABC, time equations capture the complexity of the processes in the model. In complex systems, not all instances of activities are the same, and they do not always consume the same quantity of resources (Everaert and Bruggeman, 2007). TDABC uses time equations for each activity and allows for multiple cost drivers and resources for each activity. Time equations can be developed "through direct observation and multiple interviews" with employees and/or managers (Demeere, 2009).

3 TIME-DRIVEN ACTIVITY-BASED COSTING SYSTEM DESIGN

Section 3 describes our healthcare provider supply chain (HPSC) TDABC methodology and field study results. Table 2 depicts the step-by-step process of our HPSC TDABC methodology.

Table 2: Healthcare Provider Supply Chain TDABC Methodology

Step Number	Description
1	Document healthcare provider supply chain operations
2	Identify activities and resources of HPSC operations
3	Estimate total cost for each resource group involved in HPSC operations
4	Estimate practical capacity for each resource group
5	Calculate unit cost for each resource group
6	Identify time drivers for each activity in HPSC operations
7	Determine required time for each activity in the HPSC operations
8	Calculate total cost of HPSC operations
9	Develop HPSC TDABC spreadsheet tool

3.1 Step 1: Document HPSC Operations

Step 1 is to understand and document the supply chain operations of the healthcare provider organization. This is achieved through the development of process maps. This step requires direct input from the managers and employees who are most familiar with the healthcare provider's supply chain processes. Data is collected through interviews with targeted employees and managers as well as direct observation of supply chain operations. From interviews and observations, the process maps provide details of the functions and activities of the healthcare supply chain operations.

In our field study, we identified five separate product supply chains through observation and personnel interviews: (1) Direct Par Replenishment (DPR), (2) Cathlab, (3) Specialty, (4) Warehouse Inventory, and (5) Operating Room (OR), which were studied and documented separately. Process maps of the five product supply chains were developed and are provided in Appendix A. From the process maps, we created general categories of supply chain functions including Ordering, Picking Receiving, Ticketing, Surgery-cart picking, and Delivering. Once the analysis was complete, all the function categories allowed us to compare and contrast among the five product supply chains and to identify potential improvements in the healthcare provider's supply chain operations. Each process map was reviewed and validated with key supply chain personnel to ensure accuracy and quality. The final process maps were used in Step 3 to identify the HC provider's supply chain activities and resources. The process map for the OR is provided here in Figure 5 as an example.

As shown in Figure 5, the HC provider's OR supply chain handles four types of SKU products: (1) Specialty SKUs, which are high-cost, low-volume items; (2) Par SKUs, which have a set reorder level; (3) Stock SKUs, which have a one day lead time and are stocked in the provider's central supply store; and (4) Non-Stock SKUs, which are not stocked in the provider's central supply store and have an average three day lead time. Each of these SKU product types has its own ordering, picking, receiving, and delivering methods. A unique function in the OR is

Surgery-Cart picking, which fills the required OR supplies for various surgeries performed at the hospital.

In our field study, we found the DPR and Cathlab product supply chains in Figures 6 and 7 respectively to be straightforward and relatively simple to map. In general, we found that the more functions and activities contained in a product supply chain the more complex the processing mapping was. With more complex supply chains, it is important to document multiple observations of each function and activity when creating process maps. This is also beneficial to refer back to during the validation with the supply chain personnel. The process maps are an added asset to the healthcare provider because they provide a clear depiction of their supply chains processes which can be used during cost reduction technique implementation and can potentially be used in future supply chain process training for employees.

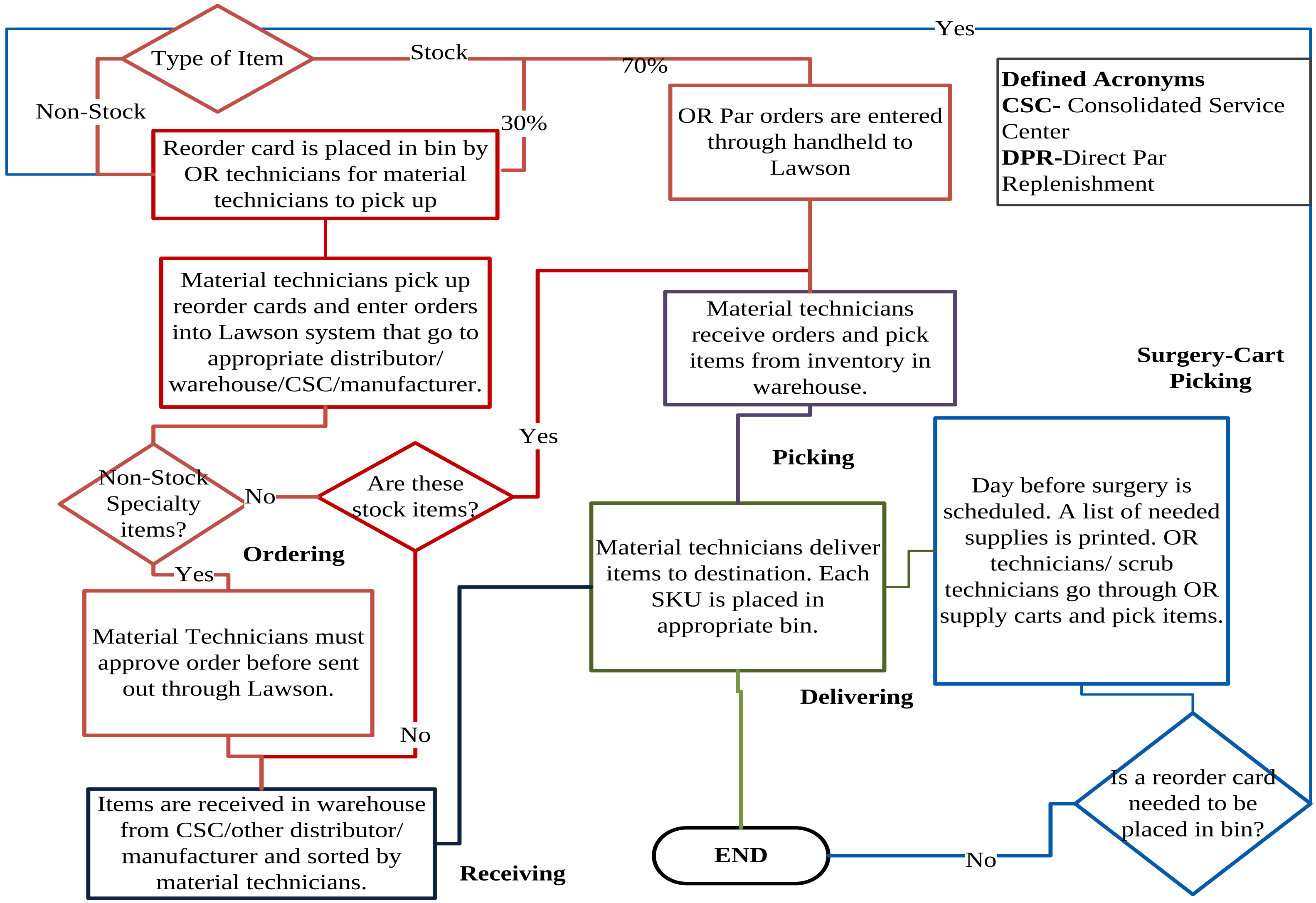

Figure 5. Operating Room Supply Chain Process Map

3.2 Step 2: Identify Activities and Resources of HPSC Operations

Step 2 consists of identifying activities conducted in and resources consumed by the HPSC operations. Activities and resources of healthcare provider's supply chain operations are found through direct observation of supply chain operations, interviews with the healthcare provider's supply chain managers and employees, and review of the HPSC process maps. Resource groups are resources who are consumed during HPSC including labor, equipment to receive and deliver products such as pallets and carts, as well as the ordering and inventory software used in the supply chain and other indirect costs.

In our field study we were asked to focus strictly on the HPSC's labor resources. In total, there were six resource groups identified; Material Technicians, Cathlab Nurses, Cathlab Technicians, Nurses, Operations Coordinator, and Operating Room Scrubs/Technicians. On average, there were four functions during each Healthcare product supply chain operation as observed in the process maps found in Appendix A; the most common functions are Ordering, Receiving and Delivering. On average, each supply chain function had two to three identified activities. Table 3 presents the identified activities and resources for the OR product supply chain of our hospital partner. The first column breaks down each function into activities, while the second column identifies the resources consumed during each activity in the OR product supply chain.

In the OR product supply chain operation, there are six functions and three resource groups. Each SKU product group has a different method of ordering. For example, all OR non-stock SKUs have a re-order card the Material Technicians have to pick up to complete order receipts, but the OR PAR SKU orders were entered through a handheld device. This made keeping track of activities for the OR functions complicated. The process maps helped us track and organize the activity variations.

Table 3. OR Supply Chain Functions, Activities, and Resource Groups

Function	Activity	Resource
Ordering	Place reorder card in bin	OR Scrub
	Pick up reorder card and check inventory	Material Technician
	Enter stock order into Lawson	Material Technician
	Enter OR Par order into Lawson	Material Technician
	Enter non-stock order into Lawson	Material Technician
	Approve specialty	Material Technician
Picking-PAR/Stock SKU	Pick PAR supplies from inventory	Material Technician
	Pick Stock supplies from inventory	Material Technician
Receiving Non-Stock SKU	Sort and consolidate supplies	Material Technician
Delivering-PAR/Stock SKU	Reach floor and room	Material Technician
	Deliver each SKU to location	Material Technician
Delivering-Non-Stock SKU	Reach floor and room	Material Technician
	Sort product once delivered to OR	Material Technician
	Deliver product to location	Material Technician
Surgery-Cart Picking	Print out list of needed supplies	OR Technician
	Go through OR carts and pick supplies	OR Technician

3.3 Steps 3-5: Total Cost, Practical Capacity, and Unit Cost for Each Resource Group

Once the resources consumed by each operation are identified, the next step is to compute the total cost of resources. Data, such as salary cost and equipment cost, can typically be found in the healthcare provider's financial records. Equations 1-3 illustrate how to calculate the total cost, practical capacity, and unit cost for each resource group for Steps 3-5 respectively.

To calculate the unit cost, cost data, work hours, and practical capacity for each resource group is needed.

To calculate unit cost, first the total monthly cost for each resource group *i* is computed utilizing Equation 1. The average hourly cost of resource group *i* is multiplied number of hours paid per week and by four weeks to give the monthly cost. The monthly practical capacity, the actual available working hours, for each resource group *i* is calculated next utilizing Equation 2. Practical capacity is calculated by multiplying the total number of available resource hours, by the practical capacity percentage (which as a rule of thumb is 80-85% for resources) (Anderson and Kaplan, 2004). Equation 3 computes the unit cost of resource group *i* by dividing the total monthly cost of resource group *i* by the monthly practical capacity of resource group *i*. The unit cost enables us to find the cost of activities in our TDABC time equations.

$$\text{Total Monthly Cost}_i = \text{hourly cost} * \text{weekly hours}_i * 4 \text{ weeks} \quad (1)$$

$$\text{Monthly Practical Capacity}_i = 0.8 * \text{weekly hours}_i * 4 \text{ weeks} \quad (2)$$

$$\text{Unit Cost}_i = \frac{\text{Total Monthly Cost}_i}{\text{Monthly Practical Capacity}_i} \quad (3)$$

Resulting from our field study, Table 4 shows the unit cost results of the six resource groups identified in the OR product supply chain. The unit costs are recorded in dollars per minute to simplify later steps in our analysis. The data for the resource groups directly related to supply chain operations was easily obtained from the hospital’s supply chain manager. However, data for resource groups who were indirectly related to supply chain operations, such as Cathlab Nurses, OR technicians, and Nurses, was not readily accessible. Complicating the matter further is the fact that not all Nurses, Cathlab Nurses, or OR Scrubs/Technicians participated equally in the supply chain activities. For example, in surgery cart picking in the OR, we found that the OR staff had a rotating shift on who completed this task. We observed that there was at least one person dedicated to this task daily. While the total number of available weekly hours for each OR Scrub/Technician was not available, we could estimate that at least forty hours (one full-time employee) were being spent on supply chain activities at the hospital. We used the same approach with the Nurses and Cathlab Nurses which was validated through interviews with supply chain managers and employees involved in the supply chain operations.

Table 4: Identified Resource Groups, Total Monthly Cost, Monthly Practical Capacity, and Unit Costs for OR Product Supply Chain.

Resources	Hourly cost	Weekly Hours	Total Monthly Cost	Monthly Practical Capacity	Unit Cost (Minute)
Material Technicians	$12.10	444	$21,489.60	1,421	$0.25
Cathlab Nurses	$27.00	40	$4,320.00	128	$0.56
Cathlab Technicians	$25.00	40	$4,000.00	128	$0.52
Nurse	$22.00	40	$3,520.00	128	$0.46
Operations Coordinator	$25.48	120	$12,320.00	384	$0.53
OR Scrubs/Technicians	$18.00	40	$2,880.00	128	$0.38

3.4 Step 6: Time Drivers for Each Activity in HPSC Operations

The time drivers for each activity conducted during HPSC operations can be identified along with the activities and resources. Time drivers are measures of a supply chain process activity that drive the amount of time it takes to complete the activity. Choosing the correct time driver is pertinent to accurately allocating resource costs to activities. It is recommended to observe the supply chain operations at a variety of times on different days of the week in order to identify time drivers that are relevant under a variety of conditions. Once the time drivers are identified, the total levels of each driver for each activity should be collected.

Table 5 shows the time drivers identified for the OR of our partner hospital as well as their associated monthly time driver levels, which were found through analysis of order receipts, for all activities in the OR supply chain. The results of our partner hospital's other four product supply chains can be found in Appendix B. We observed our provider partner's supply chain operations multiple times on different days throughout a two month period to allow us to identify time drivers under a variety of conditions. In certain cases, time driver levels such as the number of reorder cards were not available through the order receipts, so we interviewed employees and managers familiar with those drivers. Once we collected the time drivers and total levels, we validated our time driver data with key supply chain personnel to ensure validity. Any discrepancies were adjusted as needed based on additional observation and/or data collection.

In our field study, we received five months of order receipt data consisting of over 105,000 rows of ordering data and over 51 columns of descriptive categories. Our recommendation would be to limit the data request to the precise list of needed time driver data. Some driver levels may not be available through historical data collection and can be obtained through interviews with experience personnel and supply chain managers.

Table 5. OR Supply Chain Functions, Activities, Time Drivers, and Monthly Amounts

Function	Activity	Time Driver	Quantity (Monthly)
Ordering	Place reorder card in bin	Number of Cards	1,326
	Pick up reorder card and check inventory	Number of Cards	1,326
	Enter stock order into Lawson	Number of Non-Par Stock Orders	238
	Enter OR Par order into Lawson	Number of Par Orders	220
	Enter non-stock order into Lawson	Number of Non-Stock Orders	1,234
	Approve specialty	Number of Specialty Orders	617
Picking-PAR/Stock SKU	Pick PAR supplies from inventory	Number of Par Stock Items	20,085
	Pick Stock supplies from inventory	Number of Non-Par Stock Items	5,990
Receiving Non-Stock SKU	Sort and consolidate supplies	Number of Non-Stock Orders	1,234
Delivering-PAR/Stock SKU	Reach floor and room	Initialization	22
	Deliver each SKU to loc.	Number of Stock Items	26,075
Delivering-Non-Stock SKU	Reach floor and room	Initialization	22
	Sort product once delivered to OR	Number of Non-Stock Packages	2,324
	Deliver product to location	Number of Non-Stock Packages	2,324
Surgery-Cart Picking	Print out list of needed supplies	Number of OR Cases	706
	Go through OR carts and pick supplies	Number of OR Cases	706

3.5 Step 7: Time Equations for Each Activity in the HPSC Operation

In TDABC, a key and unique component is the time equation required for each activity. We chose TDABC as our method for HPSC costing because we believe this type of time requirement data collection is more efficient and effective for healthcare providers than traditional ABC data collection. In traditional ABC, employees are asked what portion of their time is spent completing certain activities (Lin, et al., 2001), which is not a simple question to answer in complex operations. In healthcare provider supply chains and other complex supply chains, estimating this portion of employee time is difficult and time-consuming. In a TDABC system, future process and cost changes can be reflected in the time driver.

Initial time equations can be developed through interviews with relevant supply chain managers and employees. Equation 4 contains a general time equation where $t_{j,k}$ is the time spent on activity *j* in operation *k*, β_o is the constant time spent on an activity independent of time driver, β_p is the time spent on activity *j* for one unit of time driver *p*, and X_p is the number of *p* time drivers for activity *j*.

$$t_{j,k}=\beta_o+\beta_p*X_p \quad (4)$$

The resulting time equations should be verified and validated through direct observation of supply chain activities. It is recommended to observe multiple times to ensure robust validation. The average time of each activity is calculated from the observed time. TDABC allows its time equations to have multiple time drivers for each activity, which may be necessary in complex systems. Data collection records can be set up in a way that allows time equation calculations to be user-friendly and easy to update if any inputs change in future operations. This enables development of a spreadsheet tool for implementing a TDABC in other HPSC systems.

We recorded time requirements in minutes in our field study. It is important to note that the recorded time requirement is in minutes per time driver. Table 6 shows the recorded times and the monthly time spent for each OR product supply chain activity, other product supply chain results can be found in Appendix B. Some of these times were challenging to capture because multiple activities were occurring at the same time. Careful observation and time recording had to be accomplished to separate the activities and assign times. Once we had the time requirements for each operation, we built our time equations for the HPSC TDABC model, as shown in Equation 5. Equation 5 illustrates a time equation for the first activity in the ordering operation for the OR product supply chain with time units in hours per month with $\beta_{cards}=2500\,\frac{cards}{month}$ and $X_{cards}=0.08\,\frac{min}{card}$.

$$t_{place\ \ card,\ ordering\ operation}=0+\frac{0.08\ min}{card}*2500\,\frac{cards}{month}*\frac{1\ hour}{60\ minutes}=3\,\frac{hours}{month} \tag{5}$$

When developing the time equations, we found it more efficient to collect required times for each activity than to ask supply chain employees for the portion of their time spent on each activity they performed. To collect the required times, the best strategy is for two people to observe the activities multiple times. This is especially true in complex functions such as receiving or ticketing when there are at least four Material Technicians are participating. As with any direct observation, additional observations will better capture the activities.

Table 6. OR Supply Chain Time Required and Monthly Time Spent

Function	Activity	Quantity (Monthly)	Time Required (Minutes)	Time Spent (Monthly Hours)
Ordering	Place reorder card in bin	1,326	0.033	0.73
	Pick up reorder card and check inventory	1,326	0.25	5.53
	Enter stock order into Lawson	238	0.25	0.99
	Enter OR Par order into Lawson	220	4.23	15.51
	Enter non-stock order into Lawson	1,234	0.25	5.14
	Approve specialty	617	1	10.28
Picking- PAR/Stock SKU	Pick PAR supplies from inventory	20,085	0.04	12.72
	Pick Stock supplies from inventory	5,990	0.04	3.79
Receiving Non-Stock SKU	Sort and consolidate supplies	1,234	1.5	30.85
Delivering- PAR/Stock SKU	Reach floor and room	22	3	1.10
	Deliver each SKU to location	26,075	0.05	22.16
Delivering- Non-Stock SKU	Reach floor and room	22	3	1.10
	Sort product once delivered to OR	2,324	1.6	61.97
	Deliver product to location	2,324	1.4	54.23
Surgery-Cart Picking	Print out list of needed supplies	706	0.5	5.88
	Go through OR carts and pick supplies	706	12.6	148.26

3.6 Step 8: Total Cost of HPSC Operations

Step 8 computes the total cost of each HPSC operation; which combines the information obtained from the previous seven steps. By using the unit cost of each resource and the time equation of each activity, the total cost can be computed. To calculate total monthly cost of each activity, we multiply the unit cost of the consumed resource group *i* of each activity *j* with the respective time equation resulting from Step 7 as shown in Equation 6. To find the total monthly cost of each supply chain *k*, we summed the total monthly cost of each activity in the supply chain as shown in Equation 7.

$$\text{Monthly Cost}_{j,k}=\text{Unit Cost}_i * t_{j,k}, \forall i,j \tag{6}$$

$$\text{Total Monthly Cost}_k = \sum_j \text{Monthly cost}_j,\ \forall k \tag{7}$$

$$\text{Total Monthly Cost} = \sum_k \text{Total Monthly cost}_k \tag{8}$$

Table 7 shows the total cost results for the OR product supply chain. All total cost results of our healthcare provider partner's product supply chains can be found in Appendix B. The Total Monthly Cost for the partner's OR product SC is $6,893.50/month, with the majority of the cost incurred by the surgery-cart picking operation. To compute the total cost of the HPSC process, we sum the total TDABC monthly cost of all five of the healthcare provider' product supply chains as shown in Table 8. The Total Monthly Cost of our partner's HPSC is $19,919.51/month, the largest product supply chain total monthly cost is the OR product SC with a monthly cost of $6,893.50.

Table 7. Step 8: Calculation of Total Cost for OR Supply Chain

Operation	Activity	Total Monthly Cost
Ordering	Place reorder card in bin	$16.41
	Pick up reorder card and check inventory	$83.57
	Enter stock order into Lawson	$15.00
	Enter OR Par order into Lawson	$234.59
	Enter non-stock order into Lawson	$77.77
	Approve specialty	$155.54
Picking- PAR/Stock SKU	Pick PAR supplies from inventory	$192.40
	Pick Stock supplies from inventory	$57.38
Receiving Non-Stock SKU	Sort and consolidate supplies	$466.61
Delivering- PAR/Stock SKU	Reach floor and room	$16.64
	Deliver each SKU to location	$335.23
Delivering- Non-Stock SKU	Reach floor and room	$16.64
	Sort product once delivered to OR	$937.35
	Deliver product to location	$820.18
Surgery-Cart Picking	Print out list of needed supplies	$132.38
	Go through OR carts and pick supplies	$3,335.85
	Total Monthly OR Cost	**$6,893.50**

Table 8. Total Costs of Supply Chains and Process

Supply Chain	Total Monthly Cost
DPR	$2,367.20
Cathlab	$3,804.08
Specialty	$3,591.46
OR	$6,893.50
Warehouse Inventory	$3,263.27
Total HPSC Monthly Cost	**$19,919.51**

3.7 Development of HPSC TDABC Spreadsheet Tool

After the completion of the field study, we developed a spreadsheet-based HPSC TDABC tool. The tool is designed to facilitate implementation of our HPSC TDABC methodology in other healthcare provider organizations. The HPSC TDABC tool includes a series of VBA input forms and EXCEL® spreadsheets where users can implement our HPSC TDABC methodology with guidance from our HPSC TDABC Tool Handbook found in Appendix C. By clicking on the “Start” button, users are navigated through the methodology to implement a TDABC for a HPSC. The tool creates a series of spreadsheets including Total Cost, Resource Utilization, Resources, and Functions worksheets. Users will input their own resource, activity, time driver, time requirement, and cost information to develop a HPSC TDABC model for each product supply chain.

To facilitate implementation, this tool is user friendly and easy to maintain and update with built-in calculations in accordance with Equations 1-8. Once all the input data is entered, the user selects the “Calculate Total Cost” button to enable completion of the Total Cost and Resource Utilization sheets. Our Total Cost and Resource Utilization sheets will allow HPSC managers with the opportunity to analyze the allocation of their costs and resource utilization according to their functions and activities. The Total Cost worksheet provides total SC cost and the portion of total cost for each function and activity in the supply chain. The Resource Utilization worksheet displays the total time spent for each resource group and also the time spent and portion of time for each function. This facilitates performance standard assessment and support identification of potential improvements to the HPSC.

One of the major challenges of implementing ABC is maintenance of the costing system and associated data (Stapleton, et al., 2004; Kaplan and Anderson, 2004). Our HPSC TDABC tool is designed to make updating and maintenance of the TDABC model less time consuming than other traditional costing systems. We used appropriate development guidelines such as logical spreadsheet organization, built-in checks for error proofing, and documentation for easy use when developing the HPSC TDABC tool.

We believe that our HPSC TDABC methodology and tool will allow HPSC managers to accurately measure and evaluate the cost of their supply chain process and to compare and contrast their various healthcare supply chain operations. The goal of the work is to enable HPSC managers to identify potential improvements and reduce costs in their healthcare supply chain operations.

Once our HPSC TDABC tool was developed, we entered the data from our field study and analyzed the total cost and employee utilization sheets for the hospital's five product supply chains. We first analyzed the functions and activities that we observed to be non-value adding such as the manual corrections of inventory levels in the ordering function of the Warehouse Inventory product supply chain. We calculated this activity to add an additional eleven hours of monthly time and $344.61 of monthly resource consumption. Another non-value adding activity we identified is the ticketing function in the Warehouse Inventory product supply chain. Currently Material Technicians spend 89 hours per month on this function resulting in a monthly cost of $1,288.44, which is 40% of the Warehouse Inventory's total monthly supply chain cost. We estimate that eliminating these two non-value activities could decrease the hospital's monthly supply chain operations cost by 8%. Through analysis of the field study results, we also found that DPR, Cathlab, and Specialty product supply chains are streamlined. However the more complex product supply chains, such as the OR and Warehouse Inventory, appear to be inefficient and have the most potential for improvement.

4 DISCUSSION AND FUTURE RESEARCH

Due to increasing healthcare costs in the United States and a lack of feasible and accurate HPSC costing methods, we were motivated to develop a methodology and tool to support accurate cost analysis of supply chain processes in a healthcare provider setting. From the literature search, we found that our research scope is unique as it incorporates both healthcare- and supply chain-related operations into a real-world application of TDABC. This is valuable because we can evaluate real world HPSC cost analysis challenges and insights into implementing TDABC in a HPSC. This research provides a HPSC TDABC costing methodology and associated spreadsheet tool to support HPSC managerial decision making. The results can be used to identify value/non-value adding activities to support improvements in HP supply chain operations.

Healthcare supply chains are complex systems within which the early 90s researchers and managers have attempted to apply an appropriate costing method. While traditional ABC has had some success, many who implemented ABC in healthcare came across a multitude of problems including challenges associated with capturing the complexity of activities, finding the correct resource consumption, and maintaining an up-to-date costing model. Through our literature search, we found that Kaplan and Anderson's (2004) TDABC model would be the most appropriate methodology to use in our healthcare supply chain scope. TDABC allows for activities to have multiple time drivers, to better capture complexity. TDABC relies on resource unit costs, allowing managers to update the number of resources without having to change the entire costing model. TDABC used time drivers and time equations to allocate costs to various activities, enabling supply chain managers to more easily collect time data as opposed to each resource's portion of time spent. Using time equations and resource unit costs enabled us to track supply chain processes costs without knowing all information such as the total number of employees who were involved in the supply chain outside of the materials management department. Time equations also alleviated maintenance issues, allowing supply chain managers to easily add activities or change time requirements for any activity.

In our field study, we worked with a mid-sized hospital in the Central U.S. to collect cost, order, and time data to implement our HPSC TDABC methodology. One major insight is the importance of managerial support while implementing TDABC. HPSC managers are able to provide invaluable support and assistance not only for data collection, but in the cooperation of employees during observation periods. We found that many employees were hesitant to speak with us and were initially on guard. Having the managers' full support and having a "kick off" meeting to explain the project was vital to the success of the study. Managers also provided expertise during the validation phase of the methodology and mapping process. They know better than anyone how the process runs and can provide assumptions for the time driver levels that are otherwise unavailable in the order receipts. Documenting any assumptions or discussions during interviews is essential for organization and accuracy.

While we are satisfied that using TDABC eliminated most of the challenges traditional ABC poses, our TDABC study posed obstacles of its own. Due to the complexity of healthcare supply chains, one challenge was mapping the processes (Appendix A). Each product supply chain had its own way of completing ordering operations. For example, in the OR, there are four OR product types, each with its own ordering method. The obstacle was to identify activities when the four different ordering operations were done simultaneously. For example, some stock items are ordered from a handheld while others have reorder cards to enter manually into the system. In order to have an accurate representation of the processes, some of the operations were not as highly detailed due to complexity in measuring these. Another challenge was obtaining all the necessary data to implement the most accurate TDABC model. Some of the time driver levels were not easily found in the order receipts or hospital database. To overcome this challenge, we relied on the expertise of the HPSC managers and employees who were able to estimate these time driver levels in order to find the true cost of activities. One setback to TDABC is not allocating 100% of the total resource costs to the supply chain activities. While this is explained because TDABC uses practical capacity of resources, it can be confusing for managers when the numbers do not add up to the total cost of resources found in Step 3.

During our literature search, multiple authors expressed concern over the amount of time it takes to implement and maintain an activity-based costing system. After our field study was complete, we conducted a cost-benefit analysis. We estimate that we spent 100 hours during the field study conducting our HPSC TDABC analysis for our partner hospital. We found a potential monthly savings of $1,633, an 8% decrease in total monthly cost, within the manual correction activity and ticketing function of the Warehouse Inventory product supply chain. We performed a sensitivity analysis where we varied the discount rate, time spent, and savings by ±25% and found that, only in extreme cases, the cost-benefit ratio would be less than one and the cost and savings would break even by 6 months. Even as an outsider to the hospital, we found TDABC to be effective and manageable to implement in our field study and the potential monthly savings of $1,633 supports TDABC as a valuable investment.

The goal of the methodology and tool is to enable HPSC managers to implement TDABC into their HPSC, increase their cost awareness to gain SC efficiency and inform related decision making. We are confident the results from our case study will enable HPSC managers to identify non-value adding activities so they can be eliminated, identify the value-adding activities, and find potential improvements to their supply chain. While our field study was limited to labor resources, in the future we hope to implement our HPSC TDABC methodology and tool in a broader HCSC scope that will demonstrate other types of resources such as equipment and software. Other future research includes analyzing the effectiveness of healthcare supply chain managerial decisions based on TDABC model results, obtaining the needed data to find the true cost of rework in the HCSC we studied, and updating our TDABC tool to keep track of HPSC improvements and devise a score-sheet system for SC managers to analyze.

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APPENDIX A- SUPPLY CHAIN PROCESS MAPS

A.1. DPR PRODUCT SUPPLY CHAIN PROCESS MAP

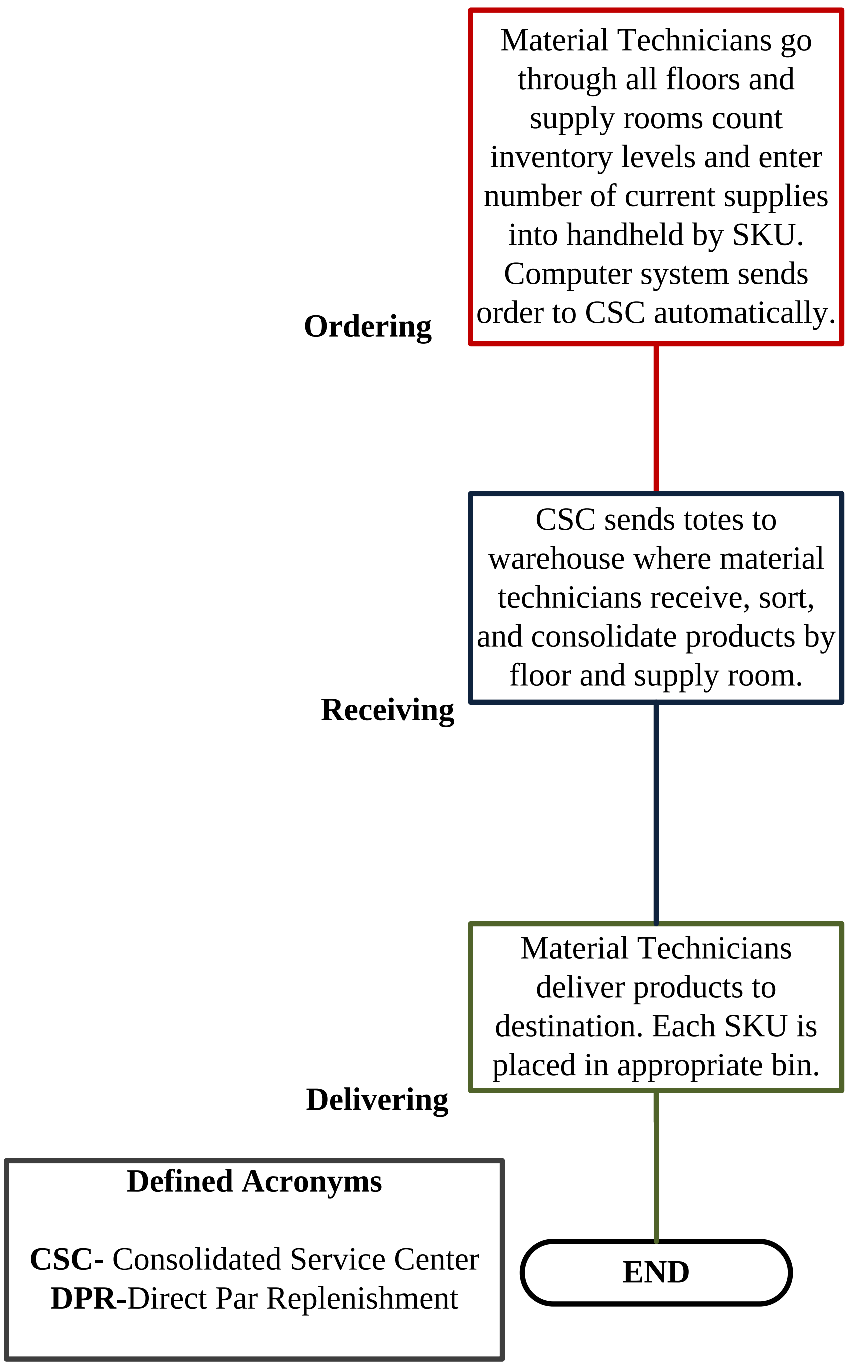

Figure 6. DPR Product Supply Chain Process Map

A.2. CATHLAB PRODUCT SUPPLY CHAIN PROCESS MAP

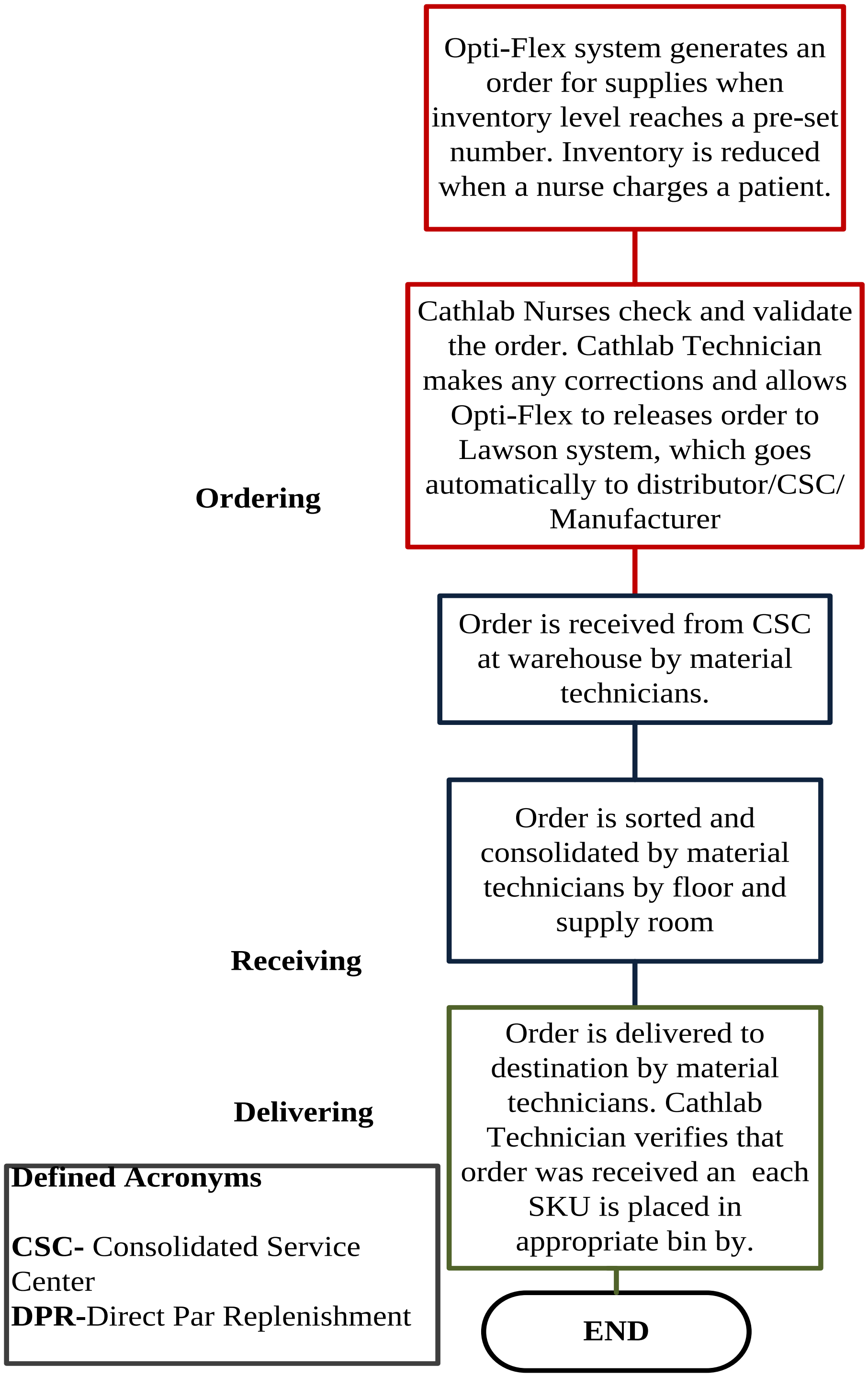

Figure 7. Cathlab Product Supply Chain Process Map

A.3. SPECIALTY PRODUCT SUPPLY CHAIN PROCESS MAP

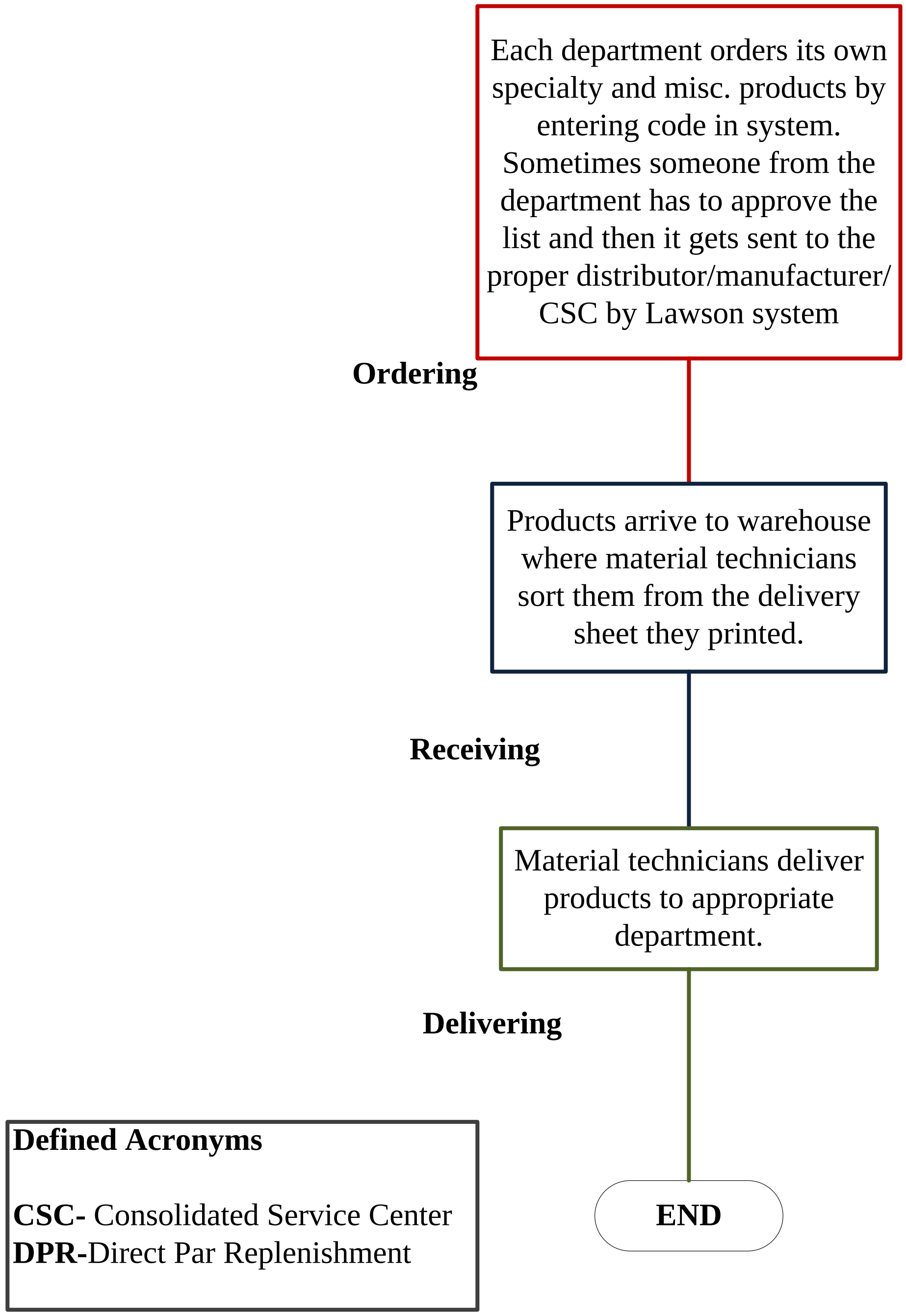

Figure 8. Specialty Product Supply Chain Process Map

A.4. WAREHOUSE INVENTORY PRODUCT SUPPLY CHAIN PROCESS MAP

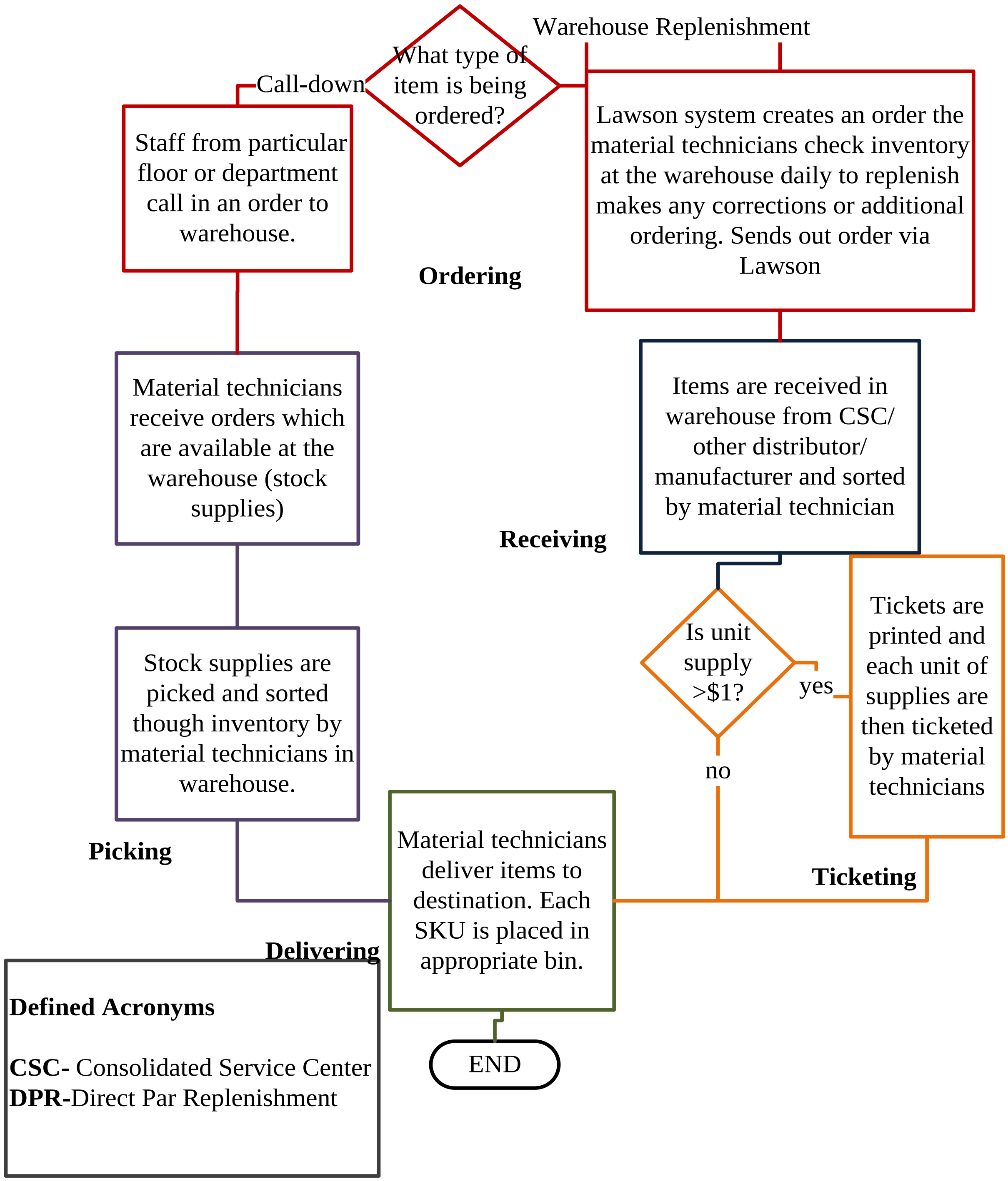

Figure 9. Warehouse Inventory Product Supply Chain Process Map

APPENDIX B- TDABC PRODUCT SUPPLY CHAIN MODELS

B.1. DPR PRODUCT SUPPLY CHAIN MODEL

Table 9. DPR Product Supply Chain TDABC Model

Function	Activity	Resource	Unit Cost	Time Driver	Quantity (Monthly)	Time required (minutes)	Time Spent (Monthly hours)	Cost (Monthly)
Ordering	Count inventory levels	Material Technician	$0.25	Number of DPR orders	9,975	0.069	12	$173.50
	Enter number into system	Material Technician	$0.25	Number of DPR orders	9,975	0.046	8	$115.67
Receiving	Bring pallets inside	Material Technician	$0.25	Number of DPR pallets	55	2.0	2	$27.73
	Sort and consolidate totes by floor and room	Material Technician	$0.25	Number of DPR totes	9,975	0.167	28	$419.93
Delivering	Reach floor and room	Material Technician	$0.25	Initialization	88	4.0	6	$88.73
	Deliver each SKU to location	Material Technician	$0.25	Number of DPR products	57,155	0.107	102	$1,541.64
							Total Monthly DPR Cost	**$2,367.20**

B.2. CATHLAB PRODUCT SUPPLY CHAIN MODEL

Table 10. Cathlab Product Supply Chain TDABC Model

Function	Activity	Resource	Unit Cost	Time Driver	Quantity (Monthly)	Time required (minutes)	Time Spent (Monthly hours)	Cost (Monthly)
Ordering	Verify OptiFlex order	Cathlab Nurse	$0.56	Number of charged Cathlab products	1,991	0.167	6	$190.39
	Check and release OptiFlex order	Cathlab Technician	$0.52	Number of Cathlab orders	723	1.5	18	$564.84
	Approve specialty order	Cathlab Technician	$0.52	Number of Cathlab specialty orders	506	1.0	8	$263.54
Receiving	Bring pallets inside	Material Technician	$0.25	Number of Cathlab pallets	4	2.0	0.133	$2.02
	Sort packages	Cathlab Technician	$0.52	Number of Cathlab packages	1,991	1.0	33	$1,036.98
	Verify receipt of orders	Cathlab Technician	$0.52	Number of Cathlab orders	723	0.465	6	$176.98
Delivering	Reach floor and room	Material Technician	$0.25	Initialization	22	2.5	1	$13.86
	Unpack packages	Cathlab Technician	$0.52	Number of Cathlab packages	1,991	1.0	33	$1,036.98
	Deliver each SKU to location	Cathlab Technician	$0.52	Number of Cathlab packages	1,991	0.5	17	$518.49
							Total Monthly Cathlab Cost	**$3,804.08**

B.3. SPECIALTY PRODUCT SUPPLY CHAIN MODEL

Table 11. Specialty Product Supply Chain TDABC Model

Function	Activity	Resource	Unit Cost	Time Driver	Quantity (Monthly)	Time required (minutes)	Time Spent (Monthly hours)	Cost (Monthly)
Ordering	Enter order	Material Technician	$0.25	Number of Specialty orders	1,612	5.0	134	$2,031.79
	Approve order	Material Technician	$0.25	Number of approvals	1,531	1.0	26	$385.94
Receiving	Bring pallets inside	Material Technician	$0.25	Number of Specialty pallets	20	2.5	1	$12.60
	Sort delivery by floor and room	Material Technician	$0.25	Number of Specialty orders	1,612	0.75	20	$304.77
Delivering	Reach floor and room	Material Technician	$0.25	Number of Specialty Locations	370	2.5	15	$233.18
	Unpack packages	Material Technician	$0.25	Number of Specialty packages	10,610	0.233	41	$623.18
							Total Monthly Specialty Cost	**$3,591.46**

B.4 OR PRODUCT SUPPLY CHAIN MODEL

Table 12. OR Product Supply Chain TDABC Model

Function	Activity	Resource	Unit Cost	Time Driver	Quantity (Monthly)	Time required (minutes)	Time Spent (Monthly hours)	Cost (Monthly)
Ordering	Place reorder card in bin	OR Scrub	$0.38	Number of Cards	1,326	0.033	0.73	$16.41
	Pick up reorder card and check inventory	Material Technician	$0.25	Number of Cards	1,326	0.25	5.53	$83.57
	Enter stock order into Lawson	Material Technician	$0.25	Number of Non-Par Stock Orders	238	0.25	0.99	$15.00
	Enter OR Par order into Lawson	Material Technician	$0.25	Number of Par Orders	220	4.23	15.51	$234.59
	Enter non-stock order into Lawson	Material Technician	$0.25	Number of Non-Stock Orders	1,234	0.25	5.14	$77.77
	Approve specialty	Material Technician	$0.25	Number of Specialty Orders	617	1	10.28	$155.54
Picking-PAR/Stock SKU	Pick PAR supplies from inventory	Material Technician	$0.25	Number of Par Stock Items	20,085	0.04	12.72	$192.40
	Pick Stock supplies from inventory	Material Technician	$0.25	Number of Non-Par Stock Items	5,990	0.04	3.79	$57.38

Receiving Non-Stock SKU	Sort and consolidate supplies	Material Technician	$0.25	Number of Non-Stock Orders	1,234	1.5	30.85	$466.61
Delivering-PAR/Stock SKU	Reach floor and room	Material Technician	$0.25	Initialization	22	3	1.10	$16.64
	Deliver each SKU to location	Material Technician	$0.25	Number of Stock Items	26,075	0.05	22.16	$335.23
Delivering-Non-Stock SKU	Reach floor and room	Material Technician	$0.25	Initialization	22	3	1.10	$16.64
	Sort product once delivered to OR	Material Technician	$0.25	Number of Non-Stock Packages	2,324	1.6	61.97	$937.35
	Deliver product to location	Material Technician	$0.25	Number of Non-Stock Packages	2,324	1.4	54.23	$820.18
Surgery-Cart Picking	Print out list of needed supplies	OR Technician	$0.38	Number of OR Cases	706	0.5	5.88	$132.38
	Go through OR carts and pick supplies	OR Technician	$0.38	Number of OR Cases	706	12.6	148.26	$3,335.85
							Total Monthly OR Cost	**$6,893.50**

B.5. WAREHOUSE INVENTORY PRODUCT SUPPLY CHAIN MODEL

Table 13. Warehouse Inventory Product Supply Chain TDABC Model

Function	Activity	Resource	Unit Cost	Time Driver	Quantity (Monthly)	Time required (minutes)	Time Spent (Monthly hours)	Cost (Monthly)
Ordering	Call in Order	Nurse	$0.46	Number of Call-ins	220	1.0	4	$100.83
	Check inventory manually	Operations Coordinator	$0.53	Number of work days	22	2.0	1	$500.98
				Number of W.I orders	1,956	0.458	15	
	Make corrections and manually order	Operations Coordinator	$0.53	Number of corrections	229	2.6	10	$344.61
				Number of Manual W.I orders	489	0.112	1	
Picking	Pick supplies from call-ins	Material Technician	$0.25	Number of Call-ins	220	0.096	0.353	$5.34
	Sort supplies from call-ins	Material Technician	$0.25	Number of items picked	220	0.067	0.244	$3.88
Receiving	Bring pallets inside	Material Technician	$0.25	Number of W.I. pallets	110	2.5	5	$69.32
	Sort and consolidate products	Material Technician	$0.25	Number of W.I. orders	1,956	1.5	49	$739.61

Ticketing	Print out stickers for supplies	Material Technician	$0.25	Number of ticket packages	1,771	0.65	19	$290.19
	Place stickers on supplies	Material Technician	$0.25	Number of ticket units	66,000	0.063	70	$998.25
Delivering	Reach floor and room	Material Technician	$0.25	Number of work days	22	3.0	1	$16.64
	Deliver each SKU to location	Material Technician	$0.265	Number of W.I packages	5,902	0.13	13	$193.41
							Total Monthly Specialty Cost	**$3,263.27**

APPENDIX C- HPSC TDABC TOOL HANDBOOK

Healthcare Provider Supply Chain

Time-Driven Activity-Based Costing Tool Handbook

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April 2014

This Healthcare Provider Supply Chain (HPSC) tool is designed to enable you as a healthcare supply chain manager to implement Time-Driven Activity-Based Costing (TDABC) in your healthcare supply chain system. Before you begin using the tool, please read this handbook in its entirety to make the implementation process easier. Table 14 shows the eight steps in the TDABC methodology. Each of the following paragraphs will provide a step-by-step description of each step and what data will be needed. The remainder of this handbook shows how to navigate through the HPSC TDABC tool. Please read the eight steps and proceeding instructions carefully to ensure correct implementation of TDABC within your supply chain process.

Table 14. HPSC TDABC Methodology

Step Number	Description
1	Document healthcare provider supply chain operations
2	Identify activities and resources of HPSC operations
3	Estimate total cost for each resource group involved in HPSC operations
4	Estimate practical capacity for each resource group
5	Calculate unit cost for each resource group
6	Identify time drivers for each activity in HPSC operations
7	Determine required time for each activity in the HPSC operations
8	Calculate total cost of HPSC operations

Step 1

Step 1 is to understand and document the supply chain functions within each of your supply chain operations. This is achieved through the development of process maps. This step requires direct input from the managers and employees who are most familiar with the healthcare provider's supply chain operations. Example operations may include the Operating Room, Emergency Room, Cathlab, ICU, and any other department or unit that has its own distinct supply chain. Data is collected through interviews with targeted employees and managers as well as direct observation of supply chain operations. From interviews and observations, the process maps provide details of the functions and activities of the healthcare supply chain operations. This step is to be done before opening the tool; only one supply chain operation can be entered in the tool at a time. If you wish to start a new TDABC model for a different healthcare supply chain operation, save the EXCEL workbook under a new name and then delete all Function and Resource worksheets, save this file under a different name, and click the START button.

Step 2

Step 2 consists of identifying activities conducted in and resources consumed by the HPSC operation. Activities and resources of the healthcare provider's supply chain operation are found through direct observation of supply chain operations, interviews with the healthcare provider's supply chain managers and employees, and review of the HPSC process maps. Resource groups are resources who are consumed during HPSC including labor, equipment to receive and deliver products such as pallets and carts, as well as the ordering and inventory software used in the supply chain and other indirect costs.

Step 3-5

Once the resources consumed by each operation are identified, the next step is to compute the total cost of resources. Data, such as salary cost and equipment cost, can typically be found in the healthcare provider's financial records. Other data needed includes total number of resources for each resource group and the total number of available hours for each resource group. The calculations are built in the worksheets which calculate the total cost of each resource group, practical capacity (we recommend that it be set at 80%), and unit cost for each resource group for Steps 3-5 respectively.

Step 6

The time drivers for each activity conducted during the HPSC operation can be identified along with the activities and resources. Time drivers are measures of a supply chain process activity that drive the amount of time it takes to complete the activity. Choosing the correct time driver is pertinent to accurately allocating resource costs to activities. It is recommended to observe the supply chain operation at a variety of times on different days of the week in order to identify time drivers that are relevant under a variety of conditions. Once the time drivers are identified, the total levels of each driver for each activity should be collected. Time driver levels can be found through order receipts or estimations provided by supply chain managers or employees.

Step 7

Step 7 requires users to record the time required to perform an activity. This should be done for all activities in the healthcare supply chain operation. Initial time requirements can be developed through interviews with relevant supply chain managers and employees. The resulting time requirements should be verified and validated through direct observation of supply chain activities. It is recommended to observe multiple times. The average time of each activity is calculated from the observed time. The time equations, which are the calculated total time spent doing an activity, is a built in calculation feature in the tool. You only have to input the average time requirements for each activity.

Step 8

Step 8 computes the total cost of the HPSC operation; which combines the information obtained from the previous seven steps. By using the unit cost of each resource and the time equation of each activity, the total cost can be computed. Calculations for total cost are built in the Tool by going to the Total Cost sheet and clicking the “Calculate Total Cost” button.

The remainder of this handbook shows how to navigate through the HPSC TDABC tool. Please read the eight steps and proceeding instructions carefully.

Start Page

When you open the HPSC TDABC EXCEL file, it should open to the Start worksheet. Macros must be enabled before opening the file; this can be done in EXCEL by going File-Options-Trust Center-Trust Center Settings-Macro Settings and select to enable All Macros. Once macros are enabled, you can begin to build your HPSC TDABC model.

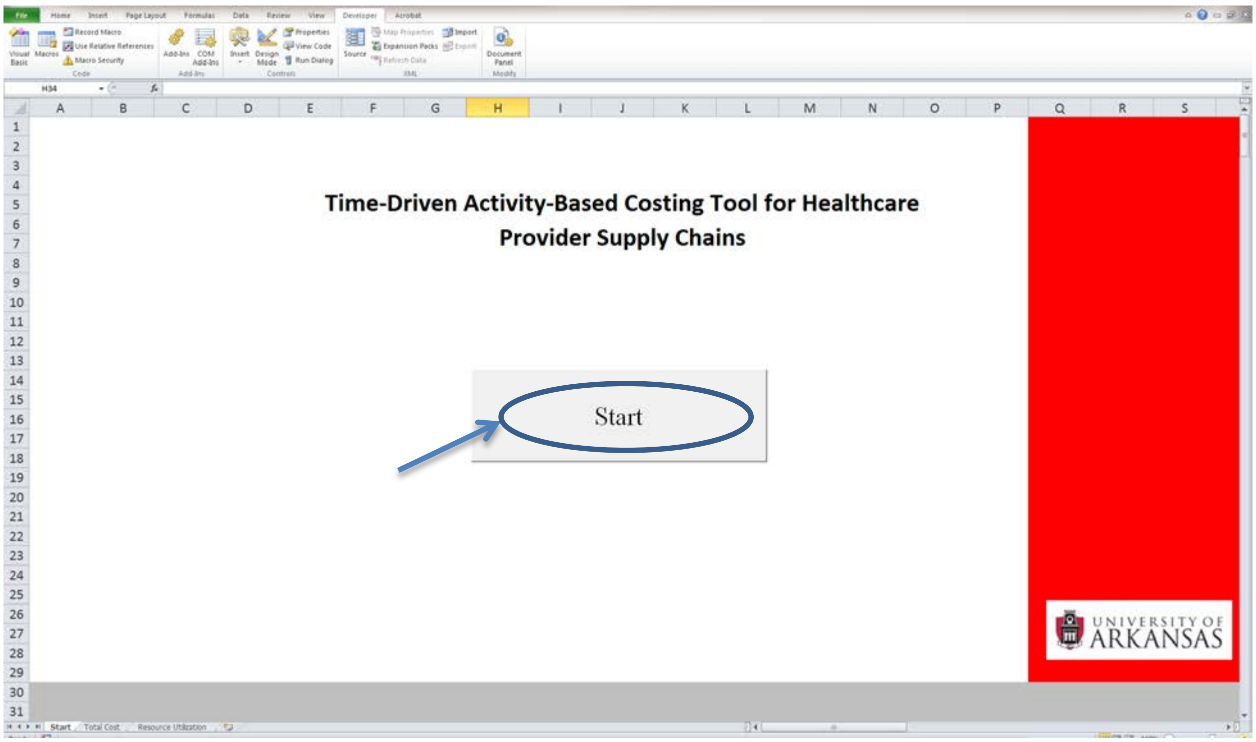


Figure 10. Start Page of HPSC TDABC Tool

Click on the Start button, and a window asking you to input the number of supply chain functions will appear. Functions of healthcare supply chain system may include ordering, receiving, picking, and delivering.

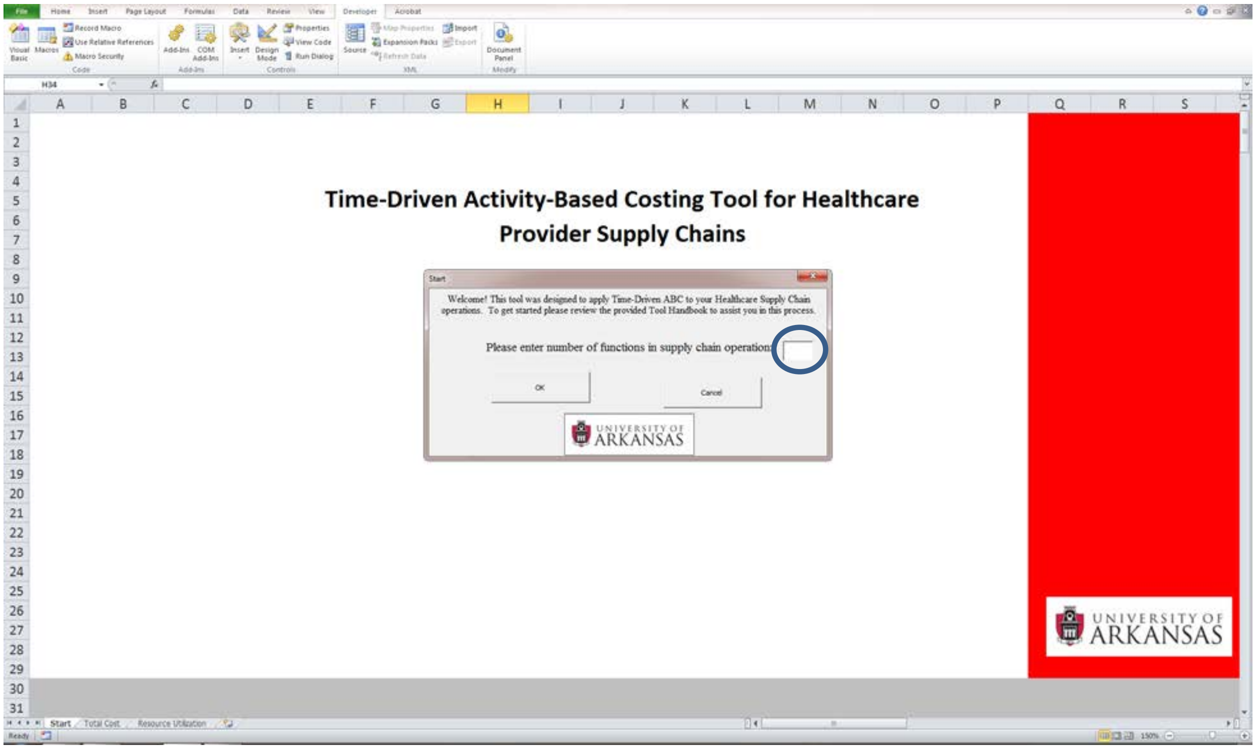


Figure 11. Function Input Form of HPSC TDABC Tool

Enter the number of functions in your supply chain of interest, and click OK in order to begin entering your data. If you leave the input box blank, you will receive an error message. Click OK and enter your number of functions.

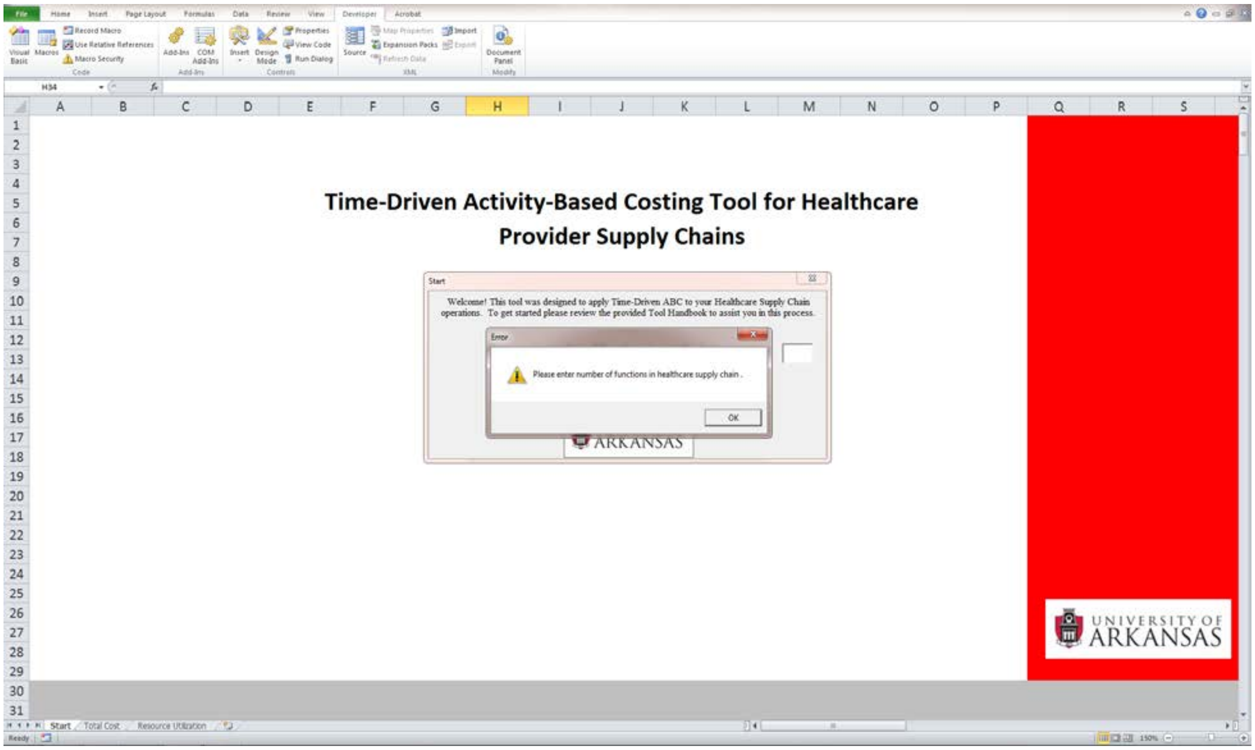


Figure 12. Incorrect Input Error Message for HPSC TDABC Tool

After the number of functions is entered, the macro-enabled workbook will generate two types of worksheets; Resources and Functions. After the worksheets appear, follow the HSPC TDABC Methodology to enter necessary data, (the circled items found below). Hyperlinks that allow you to navigate to all other worksheets in EXCEL workbook can be found in each worksheet under "Hyperlinks to Sheets." This will enable you to easily navigate between worksheets to make any changes and update calculations.

In this tool inputs cells are colored red, in the Resources worksheet, you must input the name of each resource along with the hourly cost, total weekly work hours, and practical capacity (usually 80-85%) available for each resource group. The maximum number of resources is set to eleven, but not all resource data rows need to be utilized if less than eleven resources are in use. All the resources you enter in the Resource worksheet must be used at least once in the Functions worksheets or an error will occur. You should enter resource data from top down and not skip rows in because the TDABC calculations will not be accurate. Calculation equations for the last three columns are built in the model and shaded in green; calculation cells do not require any input.

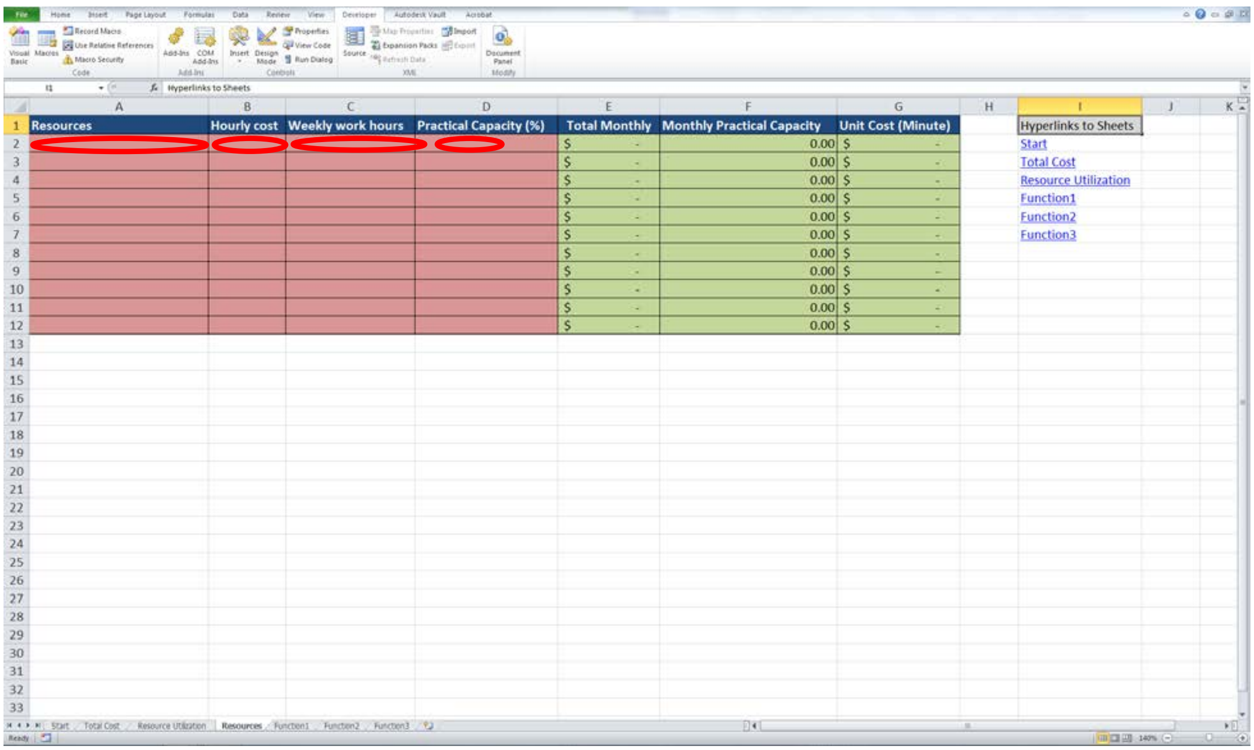


Figure 13. Resource Worksheet Sample for HPSC TDABC Tool

In the Function worksheet, you must enter name of each SC activity and consumed resource along with the time drivers, quantity, and time required for each activity (shaded in red). When entering resources in the Function worksheets, you need to make sure to type it exactly as you did in the Resources, Total Cost, or Resource Utilization worksheet will not function properly. Be certain to use exact capitalization and punctuation. The maximum number of activities is set to eleven but not all have activity data rows need to be filled. Activity data must be entered from the top down, do not skip rows or the calculations will be inaccurate. Calculation equations for the resource group unit cost, time spent, cost, and total monthly function cost are built in the model (shaded in green).

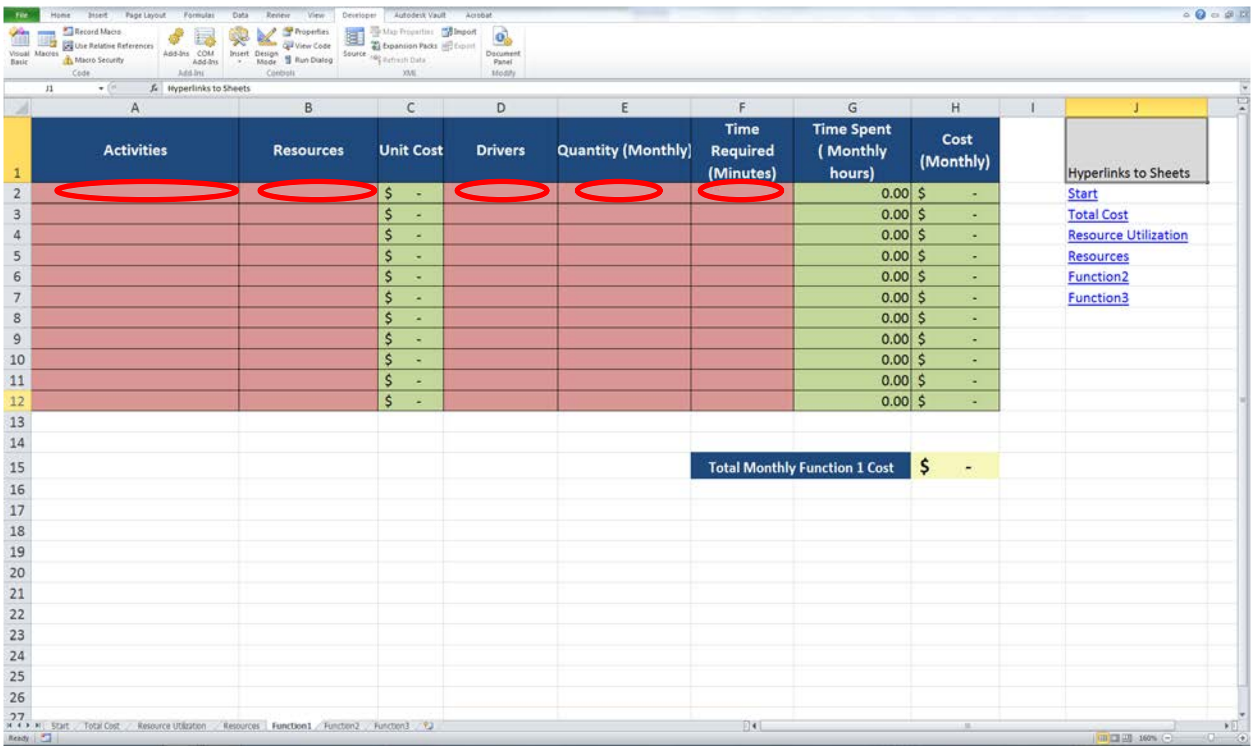


Figure 14. Function Worksheet Sample for the HPSC TDABC Tool

Once all the data has been entered in the Resources and Function worksheets, go to the Total Cost worksheet and press the Calculate Total Cost button to calculate the total monthly process cost of each function in the healthcare supply chain. All cells showing results are shaded in yellow. Below is what the Resources and Function worksheets will look like once the Calculate Total Cost button is clicked.

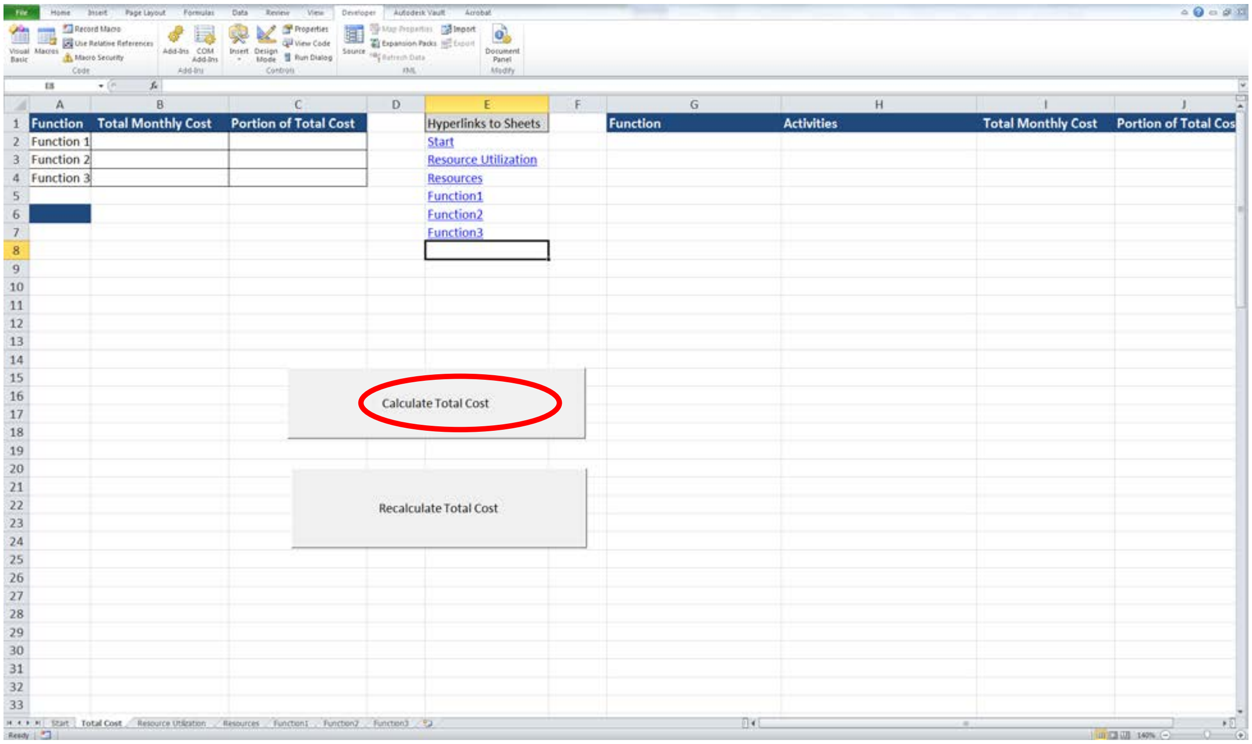
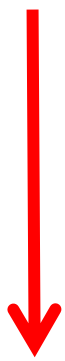
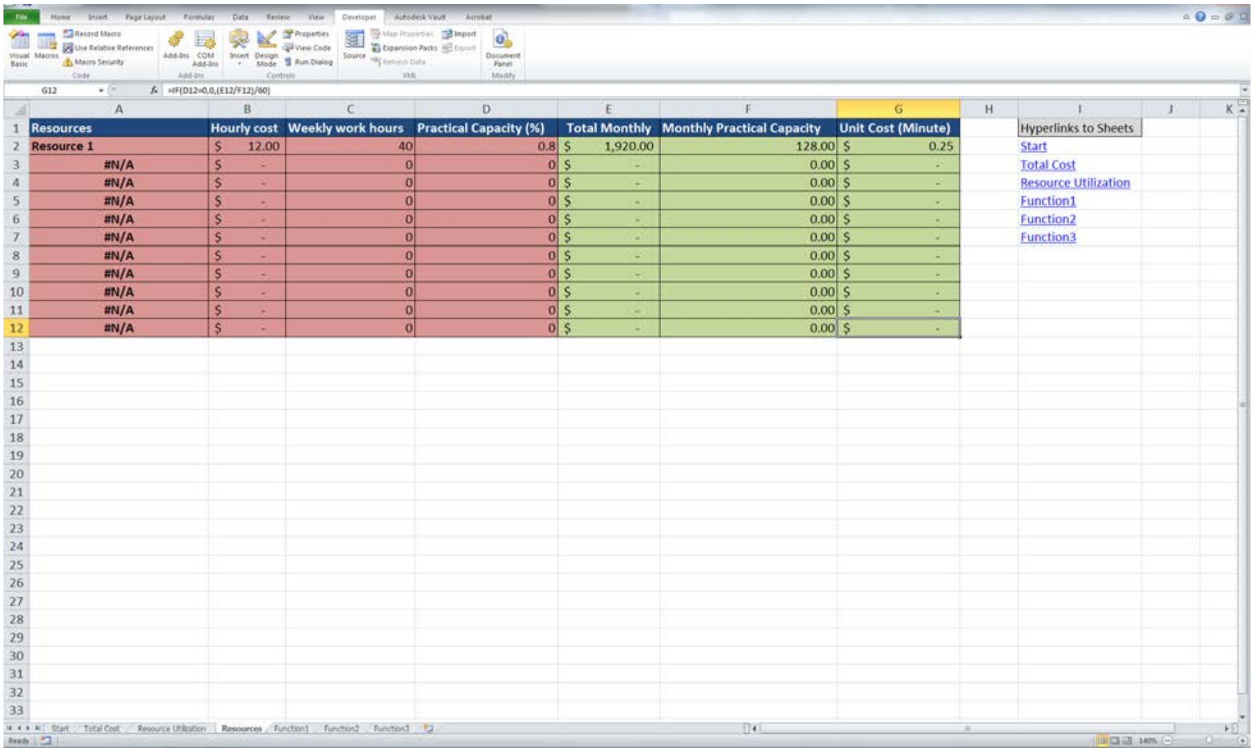


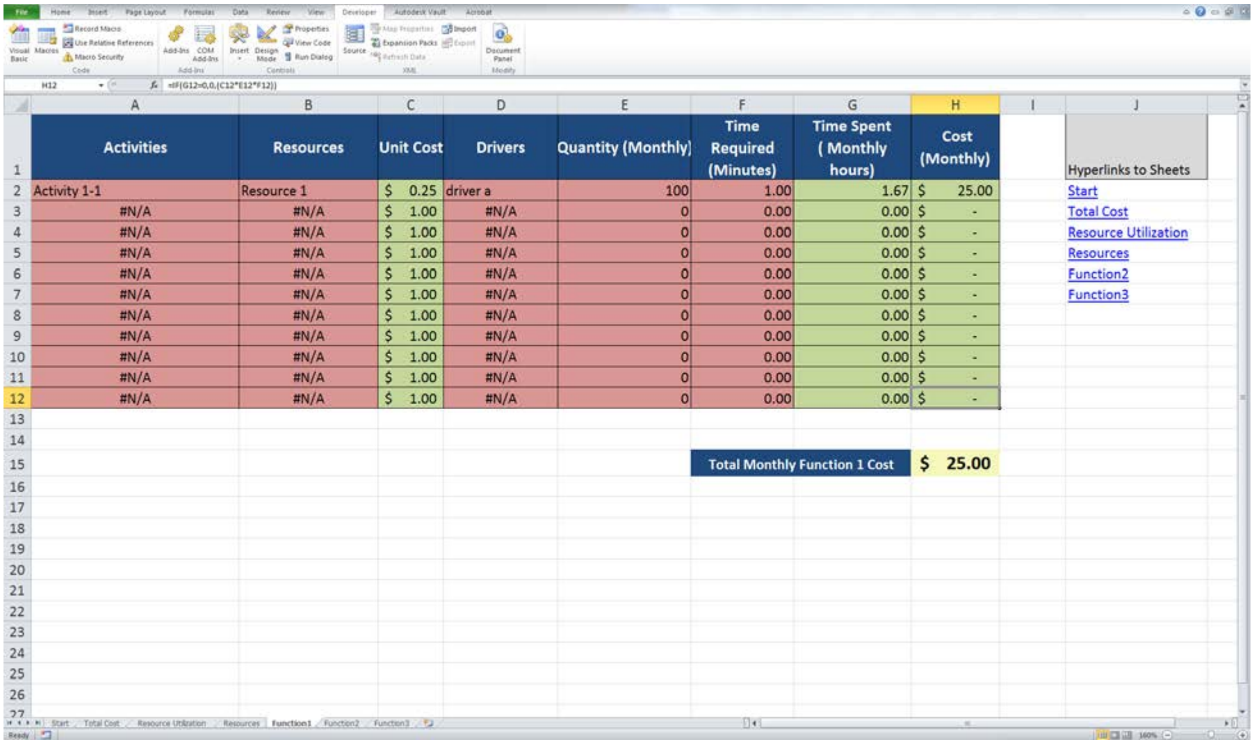
Figure 15. Total Cost Worksheet Sample for the HPSC TDABC Tool





Resources	Hourly cost	Weekly work hours	Practical Capacity (%)	Total Monthly	Monthly Practical Capacity	Unit Cost (Minute)
Resource 1	$ 12.00	40	0.8	$ 1,920.00	128.00	$ 0.25
#N/A	$ -	0	0	$ -	0.00	$ -
#N/A	$ -	0	0	$ -	0.00	$ -
#N/A	$ -	0	0	$ -	0.00	$ -
#N/A	$ -	0	0	$ -	0.00	$ -
#N/A	$ -	0	0	$ -	0.00	$ -
#N/A	$ -	0	0	$ -	0.00	$ -
#N/A	$ -	0	0	$ -	0.00	$ -
#N/A	$ -	0	0	$ -	0.00	$ -
#N/A	$ -	0	0	$ -	0.00	$ -
#N/A	$ -	0	0	$ -	0.00	$ -

Figure 16. Complete Resources Worksheet Sample for the HPSC TDABC Tool



Activities	Resources	Unit Cost	Drivers	Quantity (Monthly)	Time Required (Minutes)	Time Spent (Monthly hours)	Cost (Monthly)	Hyperlinks to Sheets
Activity 1-1	Resource 1	$ 0.25	driver a	100	1.00	1.67	$ 25.00	Start
#N/A	#N/A	$ 1.00	#N/A	0	0.00	0.00	$ -	Total Cost
#N/A	#N/A	$ 1.00	#N/A	0	0.00	0.00	$ -	Resource Utilization
#N/A	#N/A	$ 1.00	#N/A	0	0.00	0.00	$ -	Resources
#N/A	#N/A	$ 1.00	#N/A	0	0.00	0.00	$ -	Function2
#N/A	#N/A	$ 1.00	#N/A	0	0.00	0.00	$ -	Function3
#N/A	#N/A	$ 1.00	#N/A	0	0.00	0.00	$ -	
#N/A	#N/A	$ 1.00	#N/A	0	0.00	0.00	$ -	
#N/A	#N/A	$ 1.00	#N/A	0	0.00	0.00	$ -	
#N/A	#N/A	$ 1.00	#N/A	0	0.00	0.00	$ -	
#N/A	#N/A	$ 1.00	#N/A	0	0.00	0.00	$ -	
					Total Monthly Function 1 Cost		$ 25.00	

Figure 17. Complete Function Worksheet Sample for the HPSC TDABC Tool

The Total Cost worksheet contains the Total Monthly Healthcare Supply Chain Cost as well as the Total Monthly Cost and Portion of the Total Cost. The Total Cost worksheet also contains the cost of each activity per function and the portion of the total function cost. Figure 18 illustrates a sample of a Total Cost worksheet. All result cells are shaded in yellow.

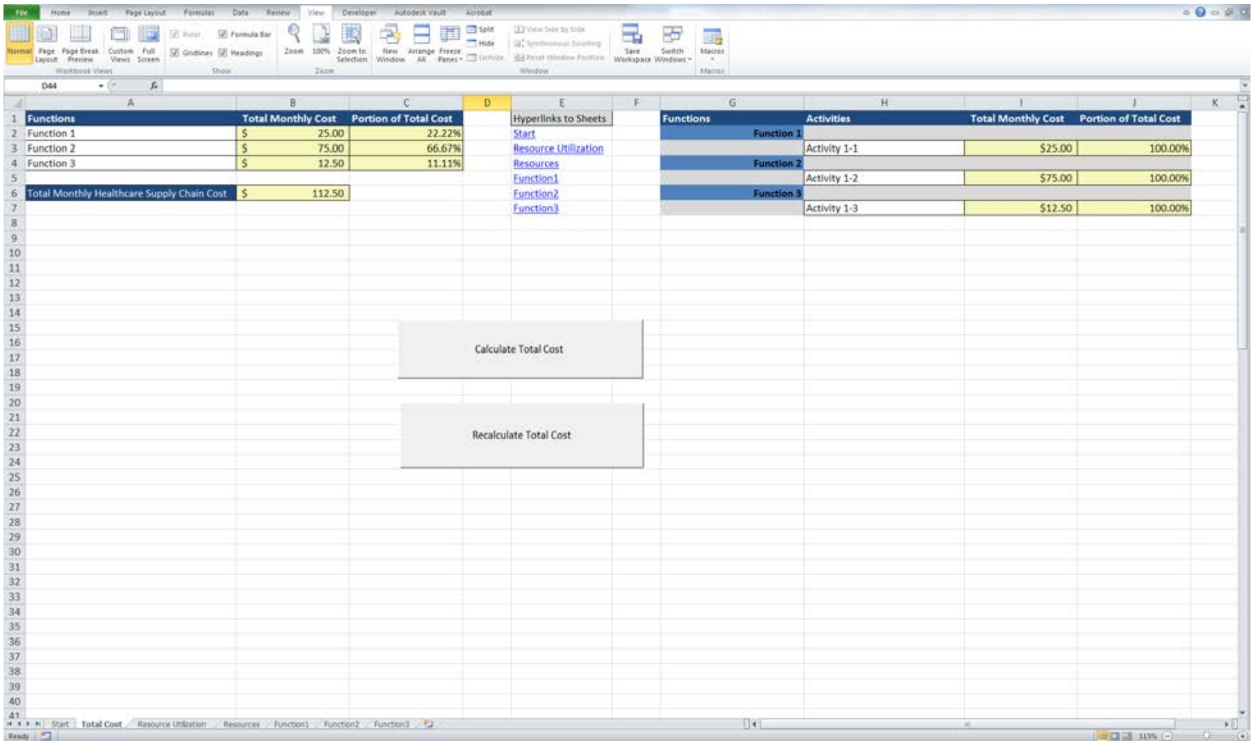


Figure 18. Calculated Total Cost Worksheet Sample for HPSC TDABC Tool

The Resource Utilization worksheet contains the total monthly time spent and utilization for each resource group. It also shows the monthly time spent per function and portion of time spent for each resource group. Figure 19 shows a calculated Resource Utilization worksheet sample. All result cells are shaded in yellow.

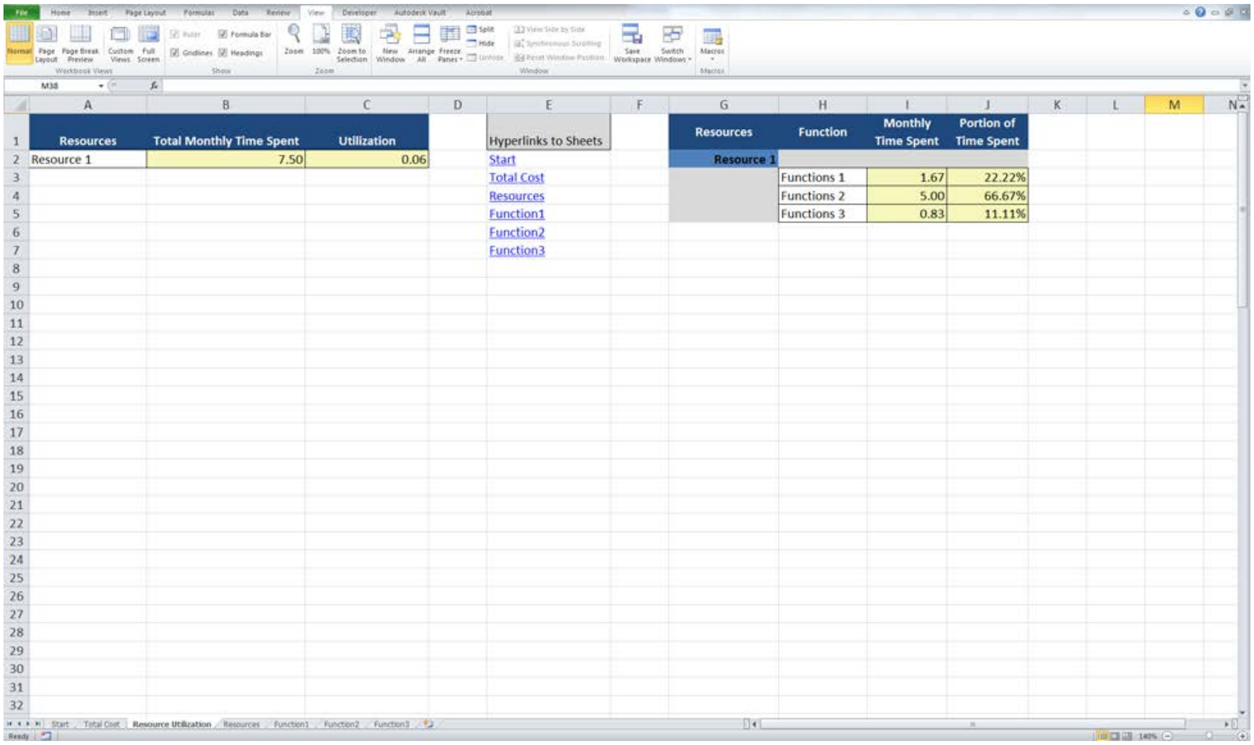


Figure 19. Calculated Resource Utilization Worksheet Sample for the HPSC TDABC Tool

If any updates are made to the Resources or Function worksheets, the Total Cost and Resource Utilization worksheets can be updated by pressing the Recalculate Total Cost button found in the Total Cost worksheet. Possible updates include adding resources or activities and changing any inputs in the Resources and Function worksheets found in this Handbook.

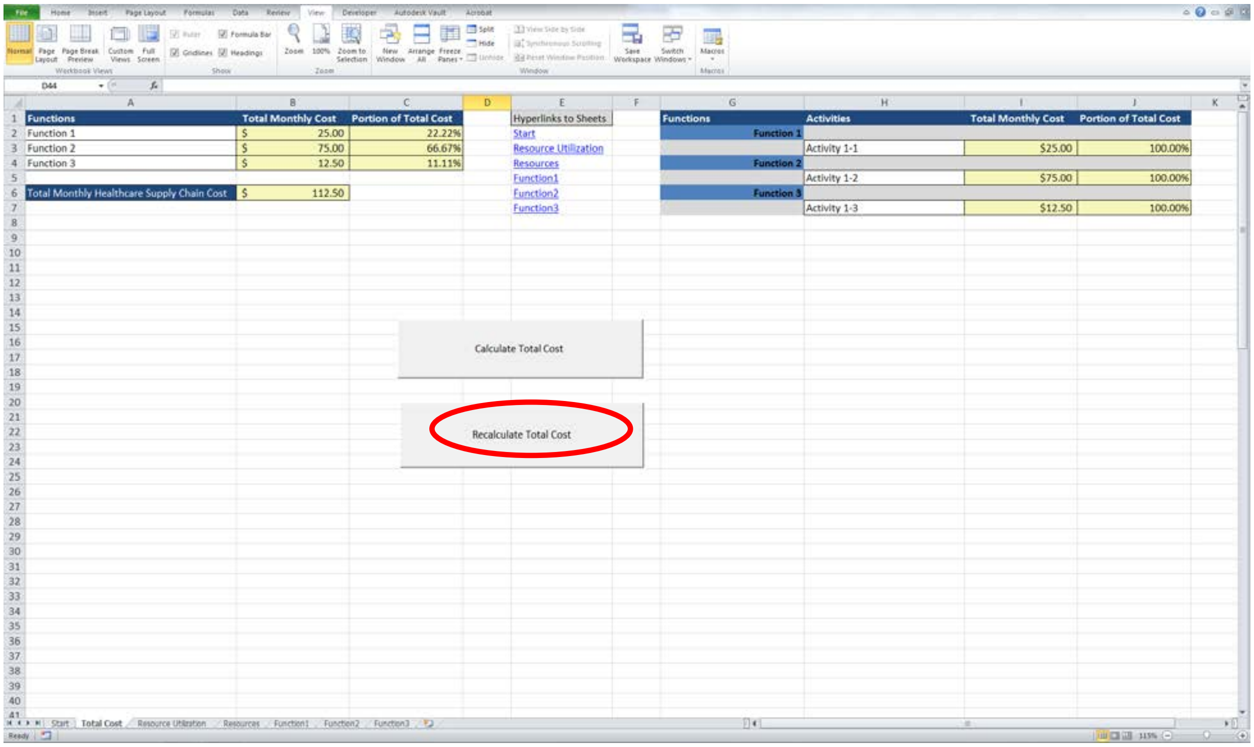


Figure 20. Recalculate Total Cost Button Location for the HPSC TDABC Tool