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USING SIMULATION TO UNDERSTAND INTERIM BRIGADE COMBAT TEAM (IBCT) MUNITIONS LOGISTICS

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ABSTRACT

Today, military leaders have limited options when reacting to the wide range of current threats existing in our world. These threats demand forces able to deploy rapidly while possessing combat capabilities to stabilize a hostile area quickly. The Army's answer to this requirement is the Interim Brigade Combat Team (IBCT).

Logistically supporting the IBCT will require the Army to develop support organizations that exploit available technologies to automate support activities, enhance situational awareness, and minimize the overall logistics footprint. The unit responsible for supporting the IBCT is the Brigade Support Battalion (BSB). One of the important missions of the BSB is to establish an ammunition transfer point (ATP) for the storage and distribution of ammunition stocks to all customer units throughout the IBCT area. This study employs an Arena 5.0 discrete-event simulation model to explore the performance of the ATP over a set of operating conditions. This set of operating conditions was selected with a statistical design of experiments using two different sets of transportation assets and ATP personnel as factors.

1 BACKGROUND

To transform the Army from its current cold-war configuration into the full-spectrum capable military of the future, the Army has developed and begun executing the Army Transformation Campaign Plan (ATCP). The plan, which is to be implemented in three phases, intends to meet the Army Chief of Staff's vision for the land force of the future. The ATCP began with the Initial Force in fiscal year 2000, continues with the Interim Force projected for activation in fiscal year 2003, and culminates with the Objective Force in 2010 (U.S. Department of the Army Headquarters 2000: 5). The Objective Force represents the completely transformed Army and will be able to deploy and sustain a Brigade Combat Team anywhere in the world in less than 96 hours, a division in 120 hours, and five divisions anywhere within 30 days. Leveraging new technologies to facilitate the projection of military force is one of the important aspects of the Objective Force.

The Army of the future will be a capabilities-based force able to quickly deploy and respond to a full spectrum of conflict—from stability and support operations to major theater wars. Today, leaders have limited options when reacting to the wide range of current threats existing in our world. Light forces are responsive but lack lethality and staying power; heavy forces possess dominating combat power but require too much time to deploy with current airlift capacities. The Army's response to this demand gap is the interim brigade combat team (IBCT). The IBCT basically fills the "medium size" gap between light forces and the heavy forces and is equipped to improve strategic responsiveness with enough firepower to resolve small-scale crises swiftly.

Organized as a mounted infantry unit, the IBCT is made up of three combined arms infantry battalions, various combat support units, and one combat service support unit called the Brigade Support Battalion (BSB). As the only combat service support unit organic to the IBCT, the BSB is solely responsible for all support functions for the brigade. The BSB is comprised of three functional companies: the headquarters and distribution company (HDC), the brigade support company, and the brigade support medical company. Figure 1 illustrates the current makeup of the HDC, under which the ammunition transfer point (ATP) operates. Compared to traditional logistics units, the BSB is smaller in size, relying heavily upon communication linkages for situational awareness, modern vehicular and material handling assets for supply distribution, and highly trained leaders for effective support to the brigade combat team. The BSB utilizes distribution-based logistics management to "maximize and prioritize the throughput of forces, supplies, and sustainment material from the port of debarkation to the warfighting unit" (Witt 1999: 41). This new approach to logistics reduces storage capacities throughout the battlefield and increases dependency on the distribution system for on-time supply deliveries.

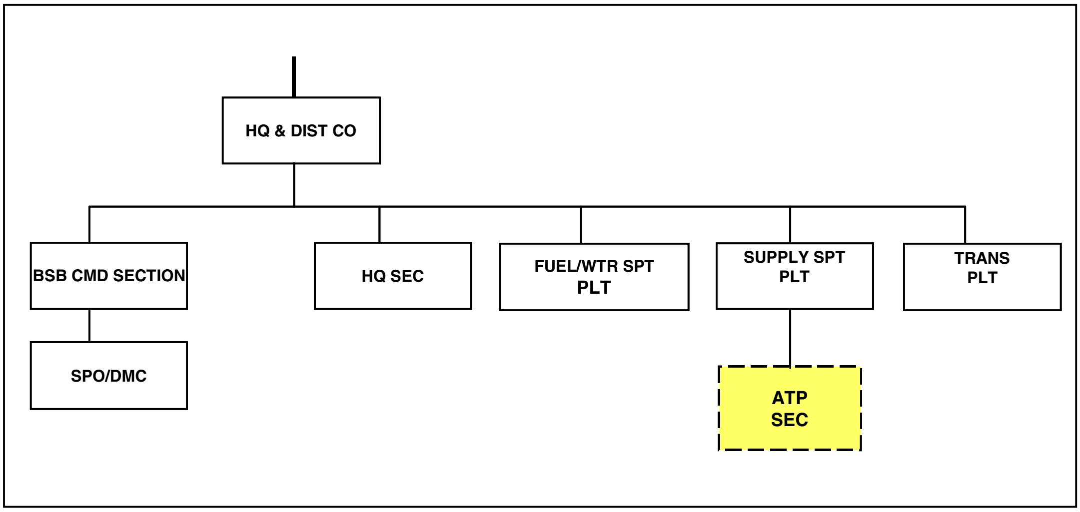

Figure 1: Organizational Structure of the HDC

One of the important missions of the BSB is to establish an ATP for the storage and distribution of ammunition stocks to all customer units throughout the IBCT area of operations. Located within the Brigade Support Area (BSA), the ATP serves as a temporary distribution point for all ammunition destined for the brigade.

In the continental United States, ammunition for individual units (e.g. infantry, field artillery) is configured on separate pallets, referred to as unit-configured loads (UCLs). Two like UCLs are then loaded on a Containerized Roll-in/Roll-out Platform (CROP). Ammunition arrives in CROPs to an aerial or seaport of debarkation to be delivered to the ATP. The UCL concept facilitates ammunition movement to and handling at the ATP, ensuring timely delivery to customers throughout the brigade. With the UCL concept in mind during the design of the ATP, the capability to reconfigure ammunition loads is limited; therefore, accurate UCLs from upstream supply nodes are essential for optimal support to the IBCT.

To effectively support the IBCT, the ATP will require an external source for the transportation of ammunition to the BSB. Two types of transportation assets are generally used to deliver ammunition to the ATP—host nation commercial assets or U.S. Army assets. Host nation assets can provide initial distribution from the ports to the BSB until additional U.S. support assets can be brought into theater. Depending on the situation, the IBCT may depend on host nation transportation assets to deliver ammunition to the ATP for the initial days of an operation until U.S. transportation assets arrive. Current doctrine puts U.S. assets in theater at day eleven. Different receipt procedures are used depending upon the type of truck delivering CROPs from the ports to the ATP.

Upon receipt of the UCLs, ATP personnel inspect and inventory loads. Once inspected, the configured loads are then temporarily stored in the ATP in anticipation of demands from the brigade customers. The HDC's Transportation Platoon (Figure 1) is responsible for transporting all classes of supply, including ammunition, to units throughout the brigade area. There are 14 trucks available for transporting all commodities, so the number of trucks available for ammunition delivery from the ATP will fluctuate depending upon the situation. For the purposes of the ATP model, it is assumed that only four trucks will be available for ammunition deliveries to the customers.

In addition to receiving, storing, and preparing UCLs for delivery, ATP personnel are also responsible for accepting ammunition turn-ins from supported units. These retrograde operations require inspection, re-configuration if necessary, and load preparation for return. Other considerations for ATP operations include site location, layout, security, and displacement. Using this information about the system and its processes, we next turn to the model development for the ATP system.

2 MODEL DEVELOPMENT

In the case of the ATP, the development of the conceptual model required several meetings with subject matter experts familiar with an ATP's operations within an IBCT environment. Like all simulation models, this model is only an approximation of the actual system. The formulation of the conceptual model begins with the determination of model boundaries. The model boundaries for this study are depicted by the outside dotted line in Figure 2. The incoming configured loads in the form of CROPs trigger the ATP process as they arrive from the theater's ports. CROPs arrive via ground transportation assets from the host nation or from available U.S. Army assets. The ATP is the focal point of our model. The resources within the ATP service the CROPs upon arrival. After receipt, inspection, and accountability processes are complete, the

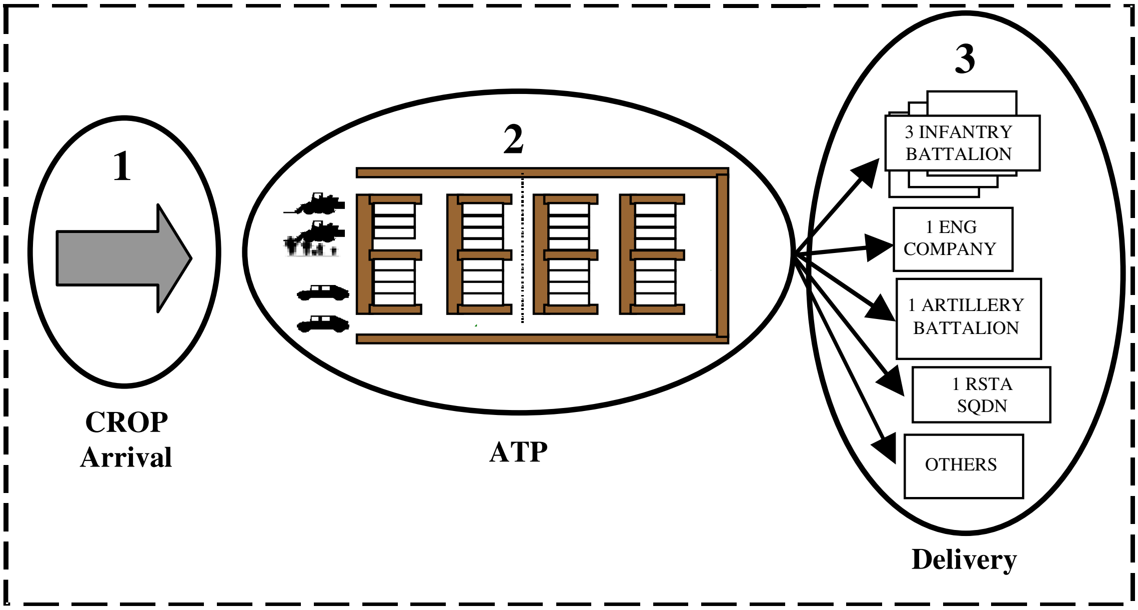

Figure 2: ATP Model Boundary

CROPs are then stored to await customer demands. Once demand information is received for a specific type of configured load, the CROPs are prepared for pick-up by the HDC transportation assets. The final part of the model is the delivery process to the customers.

Before beginning the model development process, a general framework was required for our ATP model. Important features such as the timeframe of the operation, the duration of the operation, the type of operation, the external environment, and battlefield distances for the scenario were needed before the model could be created. Subject matter experts from Army Combined Arms Support Command (CASCOM) and Fort Lewis provided information for these general assumptions. The assumptions were made with a basic understanding of current IBCT doctrine, a focus on the model purpose and performance metrics, and the understanding that the model must be as realistic as possible for valid analysis. Details on specific assumptions and distributions used for various processes can be found in Bertulis (2002).

Like most discrete-event simulation programming languages, Arena relies on entities to drive activities and events within the simulation model. In the ATP model there are two types of entities created. The first type is the *CROP entity*. These entities represent unit-configured loads built into CROPs for a specific type of unit (Field Artillery, Infantry, Engineer, etc.). CROP entities are transported throughout the model using Arena's transporter constructs. These constructs allow the analyst to model many types of material-handling systems. In the case of the ATP model, all U.S. Army truck assets and all host nation support trucks are modeled as transporters moving CROP entities from the ports through the ATP to the customer units. The second type is the *logic entity*. Logic entities have no physical significance, but they trigger events that change conditions of the ATP or collect information for analysis.

This study is specifically designed to measure throughput and other related metrics for the ATP system. Although several different measures are tabulated within the ATP model, the performance measure of interest for our analysis is the average short tons of ammunition delivered (more is better).

2.1 CROP Arrival Process

The CROP arrival process depicts the actions associated with bringing CROPs into the theater via airlift and then delivering the CROPs to the ATP via ground transportation assets. In essence, this component of the model addresses the unloading of the aircraft, the staging of ammunition CROPs, and the delivery of CROPs to the ATP by appropriate trucking assets.

Two types of vehicles bring CROPs to the ATP under the IBCT concept—host nation assets and U.S. Army truck assets. Host nation support trucks can transport only one CROP per lift and U.S. Army trucks transport two CROPs per lift. The type of truck available is dependent on the operational situation. For the purposes of the ATP model, we assume that host nation contract support is available for the initial ten days of the operation. The mission to deliver CROPs to the ATP is transferred to the U.S. Army on day eleven.

2.2 ATP Operation

This component of the model describes the events associated with receiving CROPs at the ATP from each of the two delivery truck types and storing the CROPs by customer type. The ATP Operation models assigned personnel and equipment as they receive and store CROPs for future demands.

Regardless of the type of delivery vehicle arriving at the ATP, both vehicles and their loads are initially inspected for accountability processing and safety. Following inspection, the procedures for the two types of vehicles differ because of security precautions. Host nation support trucks are prohibited from entering the ATP; therefore, the CROP entity is transferred, or cross-loaded, from the host nation truck to an internal ATP truck. From there, the host nation truck returns to the port, while the ATP truck transports the single CROP to its appropriate storage location within the ATP. U.S. Army truck assets carrying two CROPs are allowed to drive escorted by an ammunition handler into the CROP storage area and drop off each CROP at the designated storage locations.

The CROPs remain in storage until the ATP receives a request from a customer. When an appropriate CROP(s) becomes available for that customer, a request is sent from the ATP for a truck. Once the truck arrives to the ATP, the CROP(s) is uploaded and then delivered to the customer using proper distances and speeds. A snapshot of the animation for the ATP operation is shown in Figure 3.

2.3 Delivery Process

This component of the model represents the actions associated with delivering unit CROPs from the ATP to each of the five customer types. Every attempt is made to incorporate a "typical distribution day" as described in the Interim Brigade Combat Team Organizational and Operational Concepts (U.S. Department of the Army 2000). The typical day for the model's transporter section includes deliveries to an array of different sized units from Battalion to Company. Not all customers receive deliveries everyday. Following the vignette scenario given, eight customers are considered for the analysis. Working within a 50km by 50km area, the delivery process begins with the receipt of a demand from one of the customers and ends when the customer receives its CROP(s) as requested. To display the array of customers throughout the battlefield, Figure 4 shows an animation snapshot of the delivery process.

2.4 Supporting Logic

The ATP model uses five types of supporting logic routines to change environmental conditions of the ATP and trigger realistic events associated with ATP operations. The logic sub-models include demand generation and communication, APOD to ATP delivery truck availability, truck assets reliability, retrograde activities, and data collection routines.

2.5 Verification and Validation

Throughout the model development, subject matter experts at CASCOM and Fort Lewis were consulted for model verification and validation.

3 ANALYSIS

To this point, we have discussed the role of the IBCT within the Army's transformation and the development of our simulation model of the IBCT's ATP. The study now continues into its final phase to analyze the throughput capability of the ATP under different conditions and to determine any significant factors on ATP operations from among those being considered.

3.1 Experimental Design

Our experiment studies total average short tons delivered as the response variable and selects three factors to vary conditions under which the ATP operates. Our purpose is to compare the average performance for each set of conditions and to identify factors that significantly effect performance. We selected delivered short tons as the response understanding that the ultimate purpose of the munitions supply chain is to provide ammunition to the warfighter at the right place at the right time to ensure combat effectiveness at all times. Delivered ammunition provides the most accurate measure for effective ATP performance. Table 1 lists the factors selected and their assigned levels for the planned experiment. We built a three-factor, two-level, balanced design model and conducted a 2^3 *factorial experiment.*

Table 1: Factors and Levels

FACTORS	LEVELS
Number of Shifts	1 – one shift 2 – two shifts
Number of Trans Platoon HEMTT-LHS vehicles	1 – one vehicles 2 – four vehicles
Number of ATP HEMTT-LHS vehicles	1 – one vehicles 2 – three vehicles

3.2 Results

Table 2 shows the treatment means for all factor level combinations over 30 replications, and Table 3 displays the results of the ANOVA. With an adjusted R-squared value of 0.968 and a model p-value of less than .0001, we see that Shifts and Trans Vehicles significantly affect the average short tons delivered to customer units within the brigade area. In addition, their interaction also significantly affects this response. A look at the interaction plot in Figure 5 shows the interaction effect between the number of shifts and the number of transportation vehicles available

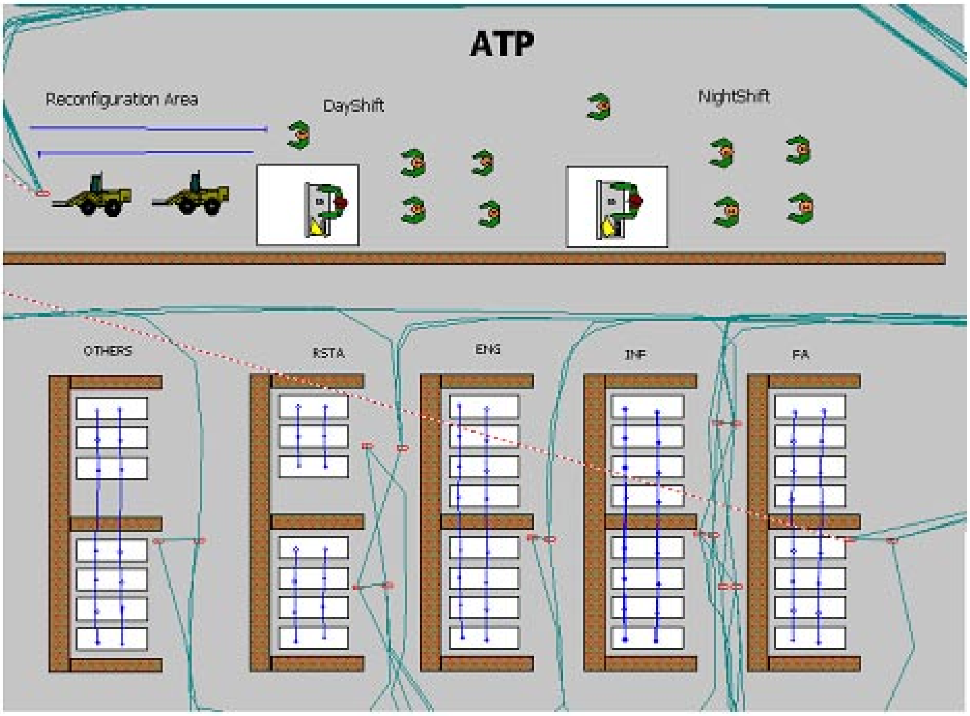

Figure 3: Animation Snapshot of ATP Operation

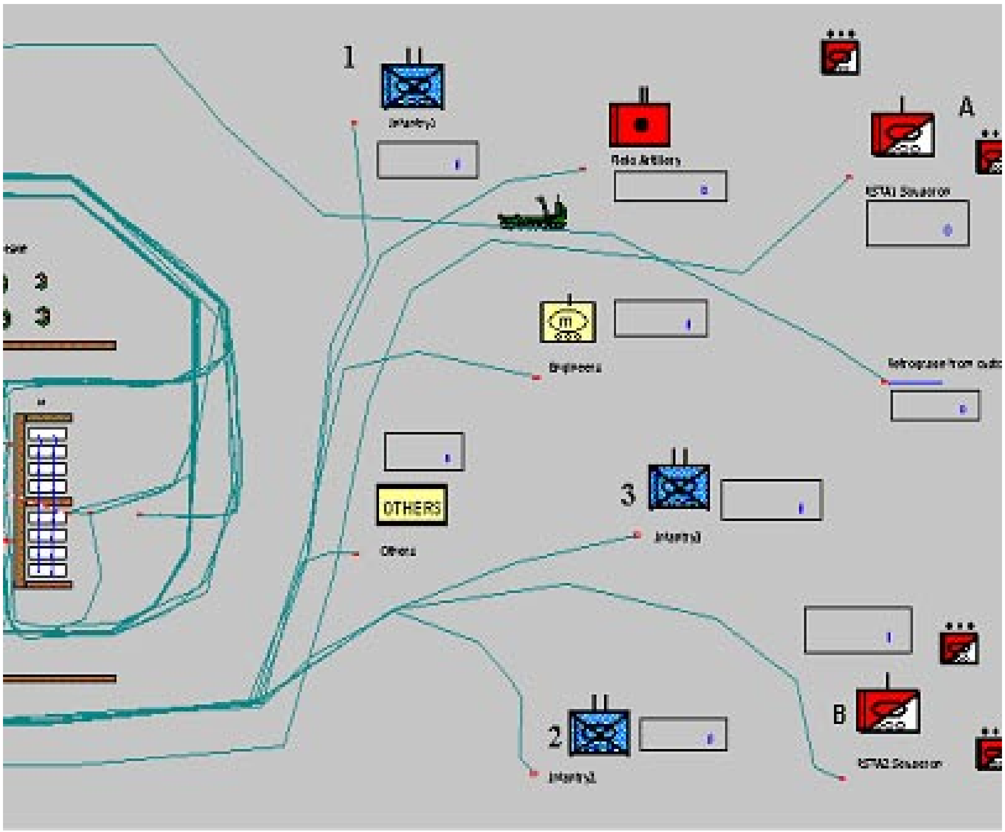

Figure 4: Animation Snapshot of Delivery Process

for delivery to customers is dramatic when the system has only one vehicle available to the ATP. We see a minimal change in the response variable for the different number of shifts when there are four vehicles available to the ATP system.

Table 2: Mean Short Tons Delivered

Number of Shifts		1		2	
Number of Trans Vehicles		1	4	1	4
Number of ATP Vehicles	1	51.05	70.91	69.23	72.61
	3	50.85	70.78	69.59	72.26

Table 3: Analysis of Variance Results

Effect Tests					
Source	Npar	DF	Sum of Squares	F Ratio	Prob > F
# of Shifts	1	1	6036.5856	2426.215	<.0001
# of Trans Veh	1	1	7879.9991	3167.117	<.0001
# of Shifts * # of Trans Veh	1	1	4270.3454	1716.33	<.0001
# of ATP Veh	1	1	0.4001	0.1608	0.6888
# of Shifts * # of ATP Veh	1	1	0.4355	0.1750	0.6761
# of Trans Veh * # of ATP Veh	1	1	1.5904	0.6392	0.4248

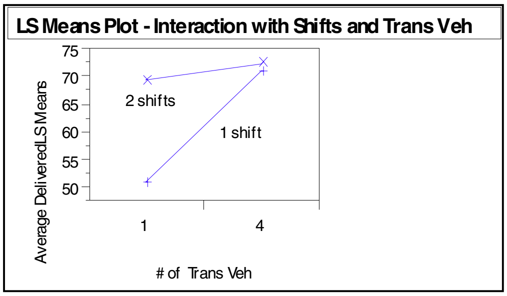

Figure 5: Interaction Plot with Shifts and Trans Vehicles

4 CONCLUSION

Our analysis uncovered the important interaction between the number of shifts and the number of transportation platoon vehicles available to the ATP operation. This important interaction tells us that throughput is very dependent upon the delivery operation. The receipt and storage processes within the ATP are important, but the significant operation is the delivery process. The results show that with two shifts and an assumed 24-hour delivery schedule, one transportation platoon truck can maintain the proper flow of ammunition to customer units. Also worth noting is that with only one shift at the ATP, the four transportation platoon assets can also meet demands during the daylight hours and limited evening delivery schedule. In addition we noted the lack of significance of the ATP vehicles. Given the information regarding the tasks and operations from the subject matter experts, the three organic transportation vehicles modeled were used for only the first ten days of the operation. The assets were needed for transloading shipments from host nation support assets delivering CROPs from theater ports. The model assumed that the echelon of U.S. Army units assigned to support the IBCT after day ten would also be equipped with the Load Handling System. Within the model, no other tasks were assigned to the ATP vehicles. Assuming these concepts are true, the ATP vehicles will not significantly influence ATP operations.

Overall, the experiments increased our understanding of the ATP operation and improved our confidence in the ATP model as an approximation of the actual system. The analysis also revealed the complexity of the ATP system. The inputs made during the development of the model will require additional validation with an actual ATP in operation.

This work is one example of on-going efforts to improve our understanding of the IBCT and its support infrastructure. Built in Arena 5.0, the model features a complete animation of the ATP system capturing the realistic movements of resources and ammunition stocks expected in future IBCT operations. The model development process relied on the opinion of subject matter experts from the Army's logistics community, current doctrine, and scenario-based training material. As such, the model captures many realistic characteristics of a future IBCT operation, provides predictions of system output, and reveals factors influencing system performance. The statistical analysis conducted also verifies model accuracy. Other verification techniques were used to ensure confidence in model outputs. Besides providing information on the ATP system, this work introduces a methodology for continued IBCT unit analysis and reveals the impressive capabilities of Arena's discrete-event simulation modeling software. We hope that future researchers will continue in the efforts already on-going in this interesting and important area.

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