

Benchmarking Warehouse Performance: A Study of Book Industry Warehouses

Georgia Tech's iDEAs project has demonstrated the feasibility of a web-based tool for benchmarking warehouse performance, using a system-based assessment method called data envelopment analysis (DEA). The Book Industry Study Group Project represents the next step in developing this performance assessment technology—a focused study of a specific industry group. By participating in the BISG benchmarking study, you will not only gain valuable insights into the performance of your own warehouse, you will contribute to a unique industry level benchmarking of warehouse performance and practices.

There are two phases to the BISG study. First, when you enter your data, you will immediately receive two types of feedback, a “system efficiency score” and a “gap analysis.” The system efficiency score is reported in two forms, the input score and the output score. Here, “input” is the set of resources used in the warehouse, and “output” is the order fulfillment accomplished. The input score is never greater than 100%, and the closer to 100%, the closer you are to maximum utilization of your resources for your given level of output. The output score is never less than 100%, and the closer to 100%, the closer you are to achieve the maximum output for your given level of resources. For either version of the system efficiency score, values far from 100% indicate significant opportunities for improvement. The second immediate feedback, the “gap analysis,” allows you to compare yourself on any specific partial productivity (single factor productivity) metric, such as lines picked per labor hour, to the best warehouse (on this metric) in your peer group. The comparison identifies the “causes” for the gap between you and the best partial productivity, which can be: scale of operation, differences in input mix, differences in output mix, and technical inefficiency. Only the latter is really under the control of the warehouse manager.

The second phase of the study is industry level “statistical benchmarking”. Because we collect a range of information on the conditions and practices in each participating warehouse, the nature of the demands on the warehouse, the labor force, etc., we can look for correlations between these factors and the warehouse system efficiency. For example, we can explain the relationship between factors like inventory turnover, or labor turnover, and warehouse efficiency. It’s like a conventional benchmarking study, but it’s statistically based, data driven, and anonymous. What we hope to do is identify industry best (and worst) practices. We can’t do this analysis, however, until all the members of the peer group have finished entering their data.

The BISG version of iDEAs tool will continue to focus on warehouse operational performance, rather than financial performance. There are only a few questions which address costs, and these questions get at aspects of warehousing that may be impossible to address otherwise. Your data will be treated as confidential and proprietary, and only the research team at Georgia Tech will have access to it.

The following form displays the data requirements for the BISG version of iDEAs. Once the data has been collected you can enter the data via the internet at <http://www.isye.gatech.edu/bisg>, e-mail the completed data form to ajohnson@isye.gatech.edu, or print the document and mail it to the following address.

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Input (resource) metrics

Input metric values are required in order to compute your warehouse system efficiency scores, and perform the gap analysis.

Labor:

Labor is measured as annual labor hours including both direct and indirect labor to perform necessary operations of receiving, moving, storing, retrieving, order picking and shipping. Some indirect labor, such as management, planning and equipment maintenance is included. However, indirect supporting personnel, such as security, cleaning staff, office assistants, accounting, human resource, customer service, and the labor assigned to value-adding activities and returns process should not be counted. Labor hours will be used because of its flexibility to include both full time and part time workforce. Headcount could also be used with equivalent 2000 hours per head count per year.

Q: What are the annual direct labor hours?

Q: What are the annual indirect hours?

Space

Space is the area (measured in sq. ft.) dedicated to the warehouse operations of receiving, put away, storing, retrieving, order picking, packing and shipping. Area for supporting activities, such as office, restroom, cafeteria or break room, is not included. Area for returns processing or value-adding services is not included either. For multi-story buildings, or mezzanines used for warehousing functions, total square footage should be reported, rather than building footprint. Multi-story buildings will be an attribute captured later to reflect the construction cost and operation environment.

Q: What is the space usage for the warehouse (sq. ft.)?

Inbound goods delivery frequency

Inbound goods delivery frequency indicates how often the warehouse receives goods shipments from suppliers. This is a simple sum over all skus. For example if the warehouse receives 20 inbound shipments of sku A last year and it received 10 inbound shipments of sku B last year and these are the only two skus in the warehouse, the inbound goods delivery frequency per year would be 30 replenishments/year.

Q: What is the total overall inbound goods delivery frequency per year?

On -hand inventory

The level of inventory is a key resource;

Q: What is the average on-hand inventory summed over all skus (measure in item units)?

Q: What is the average on-hand inventory summed over all skus (measure in dollars)?

Investment

Specialized storage equipment or material transporting equipment can be purchased and should affect the operational performance of the warehouse. Here is a list of several types of specialized equipment. Please simple inventory the equipment in your warehouse by writing the quantity next to each equipment type. If there is equipment in your warehouse not on this list please pick the most similar type of equipment listed and count those pieces of equipment in the most similar category.

Vehicles	Quantity	Conveyor	Quantity
Pallet Trucks		Non-powered Roller (total ft.)	
Walkie Stackers		Powered Roller (total ft.)	
Sit-down counterbalance		Powered Belt (total ft.)	
Stand-up Counterbalance		Skate Wheel (total ft.)	
Straddle Trucks		Tow Line (total ft.)	
Straddle Reach Trucks		Pallet Conveyor (total ft.)	
Side-loader Trucks		Extensible (# of units)	
Turret Trucks		Tilt-Tray Sorter (# chutes)	
Hybrid Trucks		Other (please itemize)	
PalletASRS Machines			
Rail-guided Order Pickers			
Wire-guided Order Pickers			
AGVs			
Manual Cart			
Single Pallet Jack			
Double Pallet Jack			
Man-abroad Pallet Jack			
Slip Sheeter			
Tugger			
Other (please itemize)			

Output metrics

Output metric values are required in order to compute your warehouse system efficiency scores, and perform the gap analysis.

Orders

Q: Total units shipped. Using the terminology below this would be how many items or eaches were sold.

Q: Total orders picked/shipped: this is orders “as shipped”; if a customer order is planned for multiple shipments, then count each shipment.

Example

Suppose the content for a shipped order is:

<u>SKU#</u>	<u>Qty</u>
10021	2 (pallet)
10032	1 (pallet)
10032	20 (case)
20011	15 (case)
30244	1 (case)
30244	30 (each)
30755	25 (each)

In this list, we have 1 customer order with: 2 pallet lines, 3 pallet items, 3 full case lines, 36 full case items, 2 broken case lines and 55 broken case items.

Broken case lines picked/shipped

“Broken case” picking means picking less than a case quantity, often referred to as “eaches”.

Q: Total annual broken case lines picked/shipped: total number of lines picked in broken case and shipped.

Q: Total annual broken case items picked/shipped: total number of items picked in broken case and shipped.

Full case lines picked/shipped

“Full case” picking means picking in full case quantities.

Q: Total annual full case lines picked/shipped: total number of lines picked in full case and shipped.

Q: Total annual full case items picked/shipped: total number of items picked in full case and shipped.

Pallet items picked/shipped

“Pallet picking” means order lines picked in full pallets; it does not include items picked as broken case or full case and subsequently palletized.

Q: Total annual pallet items picked/shipped: total number of items (pallets) picked in pallets and shipped.

Q: Total annual pallet lines picked/shipped: total number of lines (pallets) picked in pallets and shipped.

SKU span

Active skus are skus that have had an order place for them in the past year. Sku span is the ratio of active skus to total skus.

Q: How many unique skus are stored in the warehouse (including skus for which there was no activity)?

Q: What is the number of active skus, i.e., skus for which you had either inbound or outbound shipments during the year?

Storage Function

Storage function describes the way items are being stored in the warehouse.

Q: What is the total number of skus picked as broken case?

Q: What is the number of pallet storage locations?

Q: How many square feet of (pallet) floor storage space is there in your warehouse?

Buffering capacity

One of the services provided by many book industry warehouses is to hold slow moving items which have very little demand over a long period time, or large press runs that are expected to serve demand over a long period.

Q: What fraction of skus in your warehouse had an inventory turnover of less than once per year?

Q: What fraction of your average inventory is in skus whose inventory turnover is less than once per year??

Q: What is the average replenishment (inbound) order quantity per sku (in units)?

Q: How many skus had replenishment (inbound) orders during the reporting period?

Q: What is the average quantity (in units) per replenish(inbound) order line?

Attributes

Attributes represent information that might be important in distinguishing warehouses or grouping them, and can be viewed as the uncontrollable (in the short run) factors that impact warehouse system efficiency. The attribute values will be required in order to conduct the industry-level benchmarking analysis.

Time period

Q: For what time period does the reported information apply?

Type of warehouse

Publishing warehouses often cannot influence the amount of product they receive, because it is determined by the size of the press run. The publishing warehouse may provide services to their suppliers, such as holding slow moving inventory in order to supply infrequent demand. Wholesale or distribution warehouses may not have such requirements.

Q: Is your warehouse owned by a publisher or is it a wholesale or distribution warehouse?

Customer types

Different types of customers place different demands on the warehouse, not only volume demands, but also lead-time, service, etc. Some typical types of customers are individuals, retailers, wholesalers or retail distribution centers.

Q: What customer types does your warehouse service? (please list all with proportion of total lines by type)

Product types

Within the book industry there are a variety of products sold. Some examples are trade paper, mass market, hard cover, children's, education, audio cassettes, videos, or calendars.

Q: What product types does your warehouse carry?(please list all with the proportion of total lines by type)

Ship-to locations

The number of customer locations handled by a particular warehouse can affect the complexity of the operation.

Q: How many unique ship-to addresses does your warehouse service?

Packaging material

In packaging customer orders, a variety of boxes can be used. Also, before a package can be sealed and shipped dunnage may be required. Here a list of the packaging materials used in the warehouse is requested. Some examples are: foam, air bags, popcorn, T-boards, boxes (length-width-height), etc.

Q: How many unique packaging materials are ordered for use in the shipping function? List the major categories

Q: How many different carton sizes are used routinely in your shipping department?

Packaging labels

Labeling also can contribute to the complexity of the shipping function.

Q: How many unique label types are used in your shipping department?

Customer defined packaging

Some customers require specific packaging methods or materials. The packaging materials may vary in type, size, or restrictions.

Q: What fraction of orders shipped require customer-specified packaging and/or labeling?

Inventory turns

Turnover is measured as total units shipped divided by average units on hand. The turnover can be estimated: from operational data as (total units shipped) divided by (average inventory in units), or from accounting information as (cost of units shipped) divided by (average value of inventory) as a proxy if the physical turnover is not available.

Q: How many times was the inventory turned last year?

Q: Is your estimate based on operational data or financial data?

Shipping consolidation

Orders generally are consolidated in the packing/shipping function according to some criterion. Please select the basis most closely resembling your operation: individual orders are consolidated, packed and shipped; multiple orders are consolidated based on carrier; or multiple orders are consolidated by delivery zones (such as zip codes or geographic region).

Q: What characteristic is the basis of order consolidation?

Value-adding activity

Value-adding activities contribute economic value to customers and may consume warehouse resources. Not all warehouses have these operations and as a result, they are not included in the DEA input/output analysis; nevertheless, the existence of value adding operations may affect system efficiency.

Q: Are there value-adding activities in your warehouse? (Yes/No)

Q: If you have value adding activities, what is the total direct plus indirect labor hours for the value adding activities during the reporting period?

Customer services provided

There are many services that can be provided to the customer during order fulfillment. Here information is being collected about the services performed in the warehouse. There are many documents that can be included with the order such as billing information, product information, or shipping summaries. Also there are services the warehouse can perform to service the customer such as labeling the products with price or product information. Also there is verification the warehouse can provide through the transportation process such as proof of delivery or advanced shipping notice or in-transit tracking. Finally, the customer may wish to update their order while it is being processed, this is called on-the-fly order adjustment.

Q: Does your warehouse provide on-the-fly order adjustment to your customers?

Q: Does your warehouse provide billing information with goods shipped to your customers?

Q: Does your warehouse provide product information with goods shipped to your customers?

Q: Does your warehouse provide shipping summaries with goods shipped to your customers?

Q: Does your warehouse provide proof of delivery?

Q: Does your warehouse provide advanced shipping notice to your customers?

Q: Does your warehouse provide in-transit tracking to your customers?

Q: Does your warehouse provide labeling services?

Q: Does your warehouse pack and hold orders?

Q: How large is your pack and hold area (sq. ft.)?

Order Description

Order characteristics

The order master (or a complete list of the orders received over a given period of time) gives a complete representation of the orders. However, to try to summarize this large set of data, two simple summary statistics are requested: the average number of titles per order (average number of lines per order) and the average number of items per title. These are two succinct measures that give insight into the types of orders handled by the warehouse.

Q: What is the average number of titles (lines) per order?

Q: What is the average number of items per title (line)?

Rush order

Rush orders are orders that are treated differently than most orders processed in the warehouse. The number of orders issued with a shorter than normal agreed lead-time divided by the total number of orders gives the fraction of orders that are rush orders. For example this could mean (but is not limited to) the order receives extra attention to insure it is process quicker or it may mean the item has a special routing to decrease processing time. But the key is the order is treated differently than most orders.

Q: What fraction of orders that are rush orders (%)?

Q: What fraction of lines picked are rush orders (%)?

Response time

This is defined as the time between the order being released to the warehouse and the order being shipped. Warehouses, depending on their customer base and their industry often are required to meet a certain response time. Warehouses with similar response time characteristics should be compared to each other. The categories are: (1) within 24 hours, (2) one to three days, (3) three days to a week, and (4) greater than one week.

Q: What is the planned average response time for your warehouse?

Q: What fraction of orders shipped meet this response time criterion?

Pick seasonality

The seasonality attribute is defined as (volume in the peak month / annual average volume per month), where volume is based on items (pieces, or units).

Q: What is the average pick seasonality in your warehouse?

Pick variability

The pick variability attribute indicates the day to day change in picking activity, and is measured as: $\max(S_L, S_H)$, where:

S_L : the maximum day to day swing in low season.

S_H : the maximum day to day swing in high season.

Swing is calculated on a percentage bases. The percentage swing is calculated as the difference between two consecutive days divided by the quantity on the second day. The percentage is recorded without a positive or negative sign.

For example, if the items shipped on day one is 10,000 items and the next day is 8,000 items, the volume on the second is down by 20% and the swing for these two days is $|(8000 - 10000)/10000| = 20\%$. If day one shipped 10,000 items and days two shipped 12,000, similarly, the volume is up by 20% and the swing is $|(12000 - 10000)/10000|=20\%$ as well.

Q: What is the average pick variability in the low season for your warehouse?

Q: What is the average overall pick variability in high season for your warehouse?

Order characteristics

Often very large orders measured either by size or by weight require special treatment. They may require additional personnel or special equipment. Similarly, very small orders can be picked in different ways to take advantage of their special characteristics. Here the average weight per order shipped and the average cube per order shipped is requested to better understand the characteristics of the orders handled by the warehouse.

Q: What is the average weight (lb) per order shipped?

Q: What is the average cube (cube ft) per order shipped?

Warehouse Equipment and Operations

Pick planning consolidation

Order picking requires pickers to travel through the warehouse selecting items. Pick planning may attempt to achieve a number of different objectives. This question attempts to identify the drivers of your pick planning. First, we need to know if your pick area is divided into pick zones, with pickers restricted to a specified zone. Next, we need to know if orders are batched for picking, and if so, what is the batching criterion.

Q: How many pick zones are in your warehouse?

Orders may be batched for picking within a zone based on carrier, destination zones (zip code or geographic region), shipment time, minimized picker travel time, or some other criterion.

Q: What criterion is used to batch orders in your picking operation?

Planning horizon

The “planning horizon” is the amount of time you have to plan the picking of an order, and limits the opportunity for optimizing the associated fulfillment operations. For example the schedule for the operation of the warehouse may be decided on Sunday for the entire week (Monday through Friday). Three categories for planning horizon are: (1) less than one day, (2) one to three days, and (3) greater than three days.

Q: What is the overall average planning horizon?

WMS

There are several commercially available warehouse management software (WMS) packages and many warehouses use systems that were created locally.

Q: Do you use a WMS package? What vendor, or developed locally?

Q: Does your WMS provide replenishment ordering strategies (reorder point and order quantity, e.g.)?

Q: Does your WMS provide picking strategies (order batching, picker routing, e.g.)?

Q: Does your WMS provide velocity-based slotting?

IT capabilities

Information technology (IT) may be used to improve the efficiency of other resources. The following questions create a description of the IT capabilities of your warehouse.

Q: Does the warehouse use pick to light? For what percentage of pick lines? For how many slots?

Q: Does the warehouse use pick to voice? For what percentage of pick lines? For how many slots?

Q: Does the warehouse use radio frequency (RF) communication to dispatch putaway? Retrieval? For what percent of lines picked?

Q: Does the warehouse use bar-coding for item identification?

Q: Does the warehouse use bar-coding for locations? For what percent of storage locations?

Q: Does the warehouse use radio frequency identification (RFID)? For what percent of skus? For what percentage of locations?

Practices

Practices are technologies or methods that might explain differences in performance.

- 1. What is your average storage space utilization based on slots occupied? What is your average storage space utilization based on storage capacity actually used?*
- 2. Do you use velocity-based slotting? For what fraction of putaway? Definition of fraction? (# of slots or number of skus?)*
- 3. Do you use task interleaving for putaway, relocate, and retrieval/picking? For what fraction of storage/retrieval transactions?*
- 4. Do you use a sortation conveyor or other automated sortation?*
- 5. Do you perform crossdocking? What percentage of items shipped are crossdocked? How many pallets are crossdocked?*
- 6. Maintenance intensity: What fraction of your operating budget is maintenance expense?*

7. *Supervision intensity: What fraction of your operating budget is supervision and management?*
8. *Labor turnover: What is your annual labor turnover for full time employees? (headcount attrition + new hires)/(beginning headcount)*
9. *What percentage of your direct labor hours are performed by temporary workers? These workers may be from a temp. agency or seasonal workers.*
10. *Is your labor force part of a collective bargaining unit? If so, what is the organization?*
11. *What is your average “inventory accuracy”, measured as the percent difference between inventory data and inventory audit? Compute as $|(actual - audit)/audit|$. (Note: you may use the results of recent audits to estimate overall inventory accuracy.)*
12. *What is your average shipment quality, measured as percent error in items shipped? Compute as sum over lines of $|(items ordered - items shipped)/items ordered|$. Note: if you ship the wrong item, the quality for that line is zero.*

Inventory fragmentation

Having the same title stored in many locations may make tracking and locating items more difficult, however, having more locations for each title increases flexibility in picker routing. Similarly, storing multiple skus in a single pick location may increase the difficulty of the retrieval process, however, combining multiple skus in a single location will decrease the number of locations and decrease the picker travel time when retrieving orders. This overall concept will be referred to as inventory fragmentation.

Q: On average (over all titles) how many locations are there for each title?

Q: On average (over all picking locations) how many titles are stored in each picking location?

Supplier and Sku Information

Supply complexity

In order to better understand how the warehouse is supplied with products, supply complexity asks about the number of suppliers from which the warehouse receives products.

Q: How many suppliers do you have?

SKU use pareto

Some warehouses have a few very fast moving items, items that are ordered and replenished frequently. Sku pareto gives insight into how many skus make up the significant portion of the items shipped. When the number of skus that represents 80% of items shipped is compared to the Sku span this gives insight into how many skus are relatively slow moving.

Q: How many unique skus represent 80% of items shipped?

SKU cube pareto

Cube here is a volume measurement, possibly in cubic feet or cubic meters. The information about how many skus represent 80% of the inventory cube gives insight into how many relatively large items are being kept in the warehouse. If this number is small compared to the

sku span, this indicates there are a few large skus being keep in the warehouse that need to be handled differently then many of the other skus.

Q: How many skus represent 80% of inventory cube?

SKU Churn

SKU churn is design to give insight into how much effort your warehouse must expend to handle changing product lines. This number is a ratio of the skus dropped last year, plus the skus added last year to the sku span (or total number of skus) at the beginning of last year.

Q: What fraction of skus changes from year to year?

$(\text{skus dropped last year} + \text{skus added last year}) / (\text{beginning total skus last year})$

Warehouse Description

Warehouse location

The geographic location of a warehouse may be a factor in determining its efficiency due to factors such as the cost of land or labor, or the nature of the local labor source

Q: Where is your warehouse located (city, state, ZIP code)?

Facility occupation duration

While operating in a particular facility, often operation managers learn better ways to match their business to the facility they occupy. Conversely, a facility that was built many years ago does not have the benefit of any recent technology or may need to be renovated to include these technologies. Therefore, it might be nature to think the duration of facility occupation may affect the efficiency of the warehouse.

Q: How long has this company been operating this warehouse?

Multi-story building

Multi-story buildings save on land costs, but may require special warehouse operations compared to a single-story building. This is a binary attribute.

Q: Is your warehouse a multi-story building? (Yes/No)

Mezzanine

Warehouses often try to increase floor space by adding mezzanines. This allows the warehouse to create additional storage space without increasing the square footage of the building. The amount of mezzanine will be measured in square footage.

Q: How many square feet of mezzanine are used in your warehouse?

Self evaluation

In putting together this questionnaire, we have tried to think of any factors that may affect warehouse performance in your industry. However, it is possible that we have overlooked a particular factor or there may be a factor that is specific to you individual operation. Please help us to identify these by answering the following questions:

Q: What are your self-identified constraints (things keeping your warehouse from being even more efficient)?

Q: What are your self-identified opportunities (things your warehouse may be able to or is taking advantage of that increase your warehouse efficiency)