Feasibility Evaluation and Quality Risk Management (QRM) for the Design of Automated Warehouse, Shipping and Transportation Operations

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Abstract *— Distributions center such as warehouse are important stage of storing materials, goods or products. Warehouses are important because they are created to store adequately the products as their main purpose. Warehouses needs to be designed accorded with the characteristics of the products. Additional stages such as shipping and transportation are important too. The automation of the shipping and transportation stages may increment the protection provided to the goods or products along the travel to their final destination. Critical factors that affect the product or materials are humidity, temperature, material degradation or any product consideration to avoid deterioration. The application of temperature and humidity monitor in the trailer may continue supervising the environmental conditions of the products after they left the warehouse. Monitor at the top, middle and bottom levels inside the trailer should be located to measure those properties.*

Key Terms *— Automated Warehouse Operations, Distribution, Shipping and Transportation, Warehouse.*

INTRODUCTION

Warehouses are facilities which provide the proper environment for the purpose of storing goods and materials that require protection from the surroundings. Warehouses must be designed to accommodate the quantity of the materials to be stored, the handling equipment, the receiving and shipping operations and associated trucking, and the needs of the operating personnel. The design of the warehouse space should be planned to best accommodate business service requirements and the products to be stored and handled.

BACKGROUND INFORMATION

In order to store correctly a product or raw material, different factor would need to be considered. The different types of warehouses include [1]:

- Heated and unheated general warehouses: provide space for bulk, rack, and bin storage, aisle space, receiving and shipping space, packing and crating space and office.
- Refrigerated warehouses: preserve the quality of perishable goods and supply materials that require refrigeration.
- Controlled humidity (CH) warehouses: they are constructed with vapor barriers and contain humidity control equipment to maintain humidity at desired levels.
- Factors in warehouse, shipping and transportation are critical as shows Figure 1.
  - ➢ Environmental controls, temperature and humidity
  - ➢ Packaging configuration, packages, drums, materials, material characteristics.
  - ➢ Product considerations, mechanisms of degradation and stability

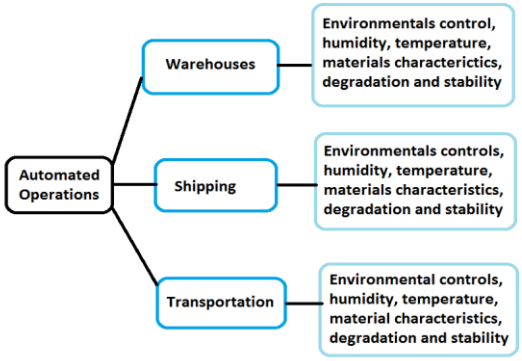

Figure 1
CTQ Diagrams for Automated Operations of a Distribution

Features already now common in warehouse designs are sophisticated materials-handling equipment, broadband connectivity access, and more distribution networks.

An extensive variety of storage alternatives, picking alternatives, material handling equipment and software exist to meet the physical and operational requirements of the warehouse. Warehouse spaces must also be flexible to accommodate future operations and storage needs as well as mission changes [1].

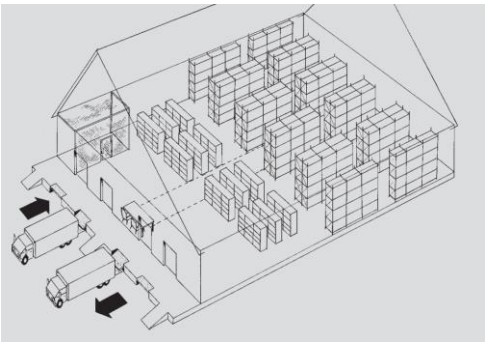

Figure 2
Sample Layout of a Warehouse

The above Figure 2 named sample layout of a warehouse [2] shows the important places inside a warehouse. It presented the storage alternative for the products, hall for picking, loading and unloading areas and the office. In the following Figure 3 is presented another example of a warehouse layout.

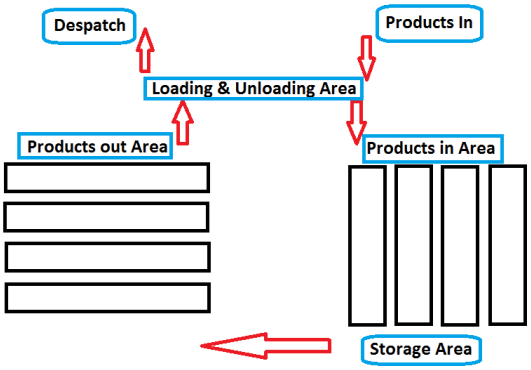

Figure 3
Sample Layout of a Warehouse Center

In the above figure the dispatch and product area is demonstrated. It presented the storage area and how it's moved to the area where the products are going out.

FACTORS IN FACILITY DESIGN

Every project should start with a list of the activities areas to be placed out and rate or prioritize them in order of the closeness adjustment to be very quick and easy task [3]. It's necessary to know the product or material to be stored in the facilities of the warehouse. Product refers to the items and the orders. Also, it's necessary to know the physical characteristics of each, including size, weight, and shape, risk of damage, condition and value. The next factor to have in mind is the quantity. In warehouse layout, quantity refers to flow as well as the amount on hand in storage or staging. Use the flow data to measure movement and handling activity. Use data on inventory level to determine required storage capacity and floor space [3].

Another factor to consider is the routing or process sequence, answering question like: Where do the products or materials and orders flow? In practice, the key input for routing is an operation process chart showing the sequence of operations for each product group and order type. It's necessary to know how much operation is developed as well as the equipment used. On some projects, you may have to make several methods decisions as input to layout planning [3].

An additional factor is the support. This refers to process services. Also, it refers to an understanding of information systems and technology such as radio frequency data collection, networking, and warehouse management software since these may enable or constrain layout plans.

The last factor to take in consideration is the timing. Timing refers to hours of operation, cutoffs, shifts, dock appointment patterns, and peak periods of all kinds. Recognize that timing refers to each activity area and processing. Timing and peaks in receiving and put-away may be quite different than those in picking and shipping. Seasonal and calendar peaks at month- or quarter-end may be

extreme. The layout must be planned with these peaks in mind.

Critical factors to consider during the facility design to a warehouse or distribution center can help a company remain competitive in a tough environment [4]. Because these facilities are critical components of the supply chain, they required a detailed planning process to ensure they meet return on investment expectation [4]. In the following section indicates four average warehouse scenarios.

- Low activity/low storage requirements: its represent the simpler and smaller warehouse operation. Rarely are automation sophisticated storage and picking mediums or devices justified for these smaller operations. In most occasions stacked pallets, simple pallets, racks and traditional shelves are used in the facility. It represents a manual handling process.
- Low activity/high storage requirements: this type of warehouse requires multilevel and high density storage. The order picking can be manual or semi manual.
- High activity/low storage requirements: These combinations suggest a very condensed forward picking area supported by simple overstocked storage. The high and frequently activity in picking orders is the reason for an automated system in picking orders.
- High activity/high storage requirements: High pick activity and high storage requirements often justifies the use of the exceedingly automated picking order systems, heavily automated material handling and sortation system and high density storage [4].

The integration of warehouse automation equipment such as conveyors, sorters and diverters with the supply chain IT infrastructure is often a missing link that can be filled only by a Warehouse Control System (WCS). Improving your warehouse management system integration directly increases your productivity and reduces your costs. Warehouse management system integration includes automated business systems interfaces with centralized data validation.

In the current warehouse environment is unlikely that one method of picking will suit the complete operations. You can split your warehouse into multiple areas with each configured to the characteristics of the products being stored and picked. It is essential to take in count the order batching, pick to trolley, voice picking. Additional, is important that you can track your orders to ensure that it is complete and consolidated before the carrier arrives. The Figure 4 shows the flow of material in a warehouse [3]. An excellent layout will have an excellent material movement with a minimal distance travel. A material movement is presented in the following Figure 4.

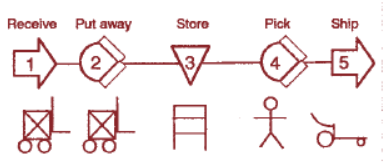

Figure 4
Flow of Material

In warehouse operations requires a great effort, the greatest expenditure of effort is in the picking process. The key of gaining efficiencies in picking is to reduce the labor time in picking orders and this can achieved in different ways. A way to minimize the picking time is having the most frequently picked items closest to the shipping areas. Also, companies achieve their competitive advantage by constantly reviewing their sales data to confirm that the items that are stored close to the shipping area are still the most frequently picked. The layout of the warehouse is important in order to achieve greater efficiencies. In a pick-to-light system, an operator will scan a bar coded label attached to a box. A digital display located in front of the pick bin will inform the operator of the item and quantity that they need to pick. Companies are typically using pick-to-light systems for their top 5 to 20% selling products. By introducing this system companies can gain significant efficiencies as it is totally paperless and eliminates the errors caused by pick tickets. Voice picking systems inform the operator of pick instructions through a headset. The

pick instructions are sent via radio frequency (RF) from the company's order management software. The system allows operators to perform pick operations without looking at a computer screen or deal with paper picks tickets. Many world class warehouse operations have adopted voice picking to complement the pick-to-light systems in place for their fast moving products [5].

INSIDE FACTORS

These factors have a dominant influence on how effectively a warehouse can be operated.

- Flow of goods in the warehouse: 'U' flow or through flow
- Equipment and people movement
- Access to stock and minimize congestion
- Identification of stock and codes
- Stock location, rotation(FIFO)
- Handling of goods in and out of the warehouse
- Supervision, safety, stock security

Warehouse halls and paths need to be properly design in order to accomplish one of the warehouse objectives, which is maximizing effective use of space. The widths in between should be adequate enough for movement of people and equipment. It is ideal to have separate doors for people on foot and for forklift trucks. Some areas should also be set aside for other warehouse activities [2]. These include:

- Areas for loading and unloading vehicle
- Staging or temporary storage areas
- Office space, washroom and lunch rooms
- Area for repacking, labeling, marking
- Area for equipment storage and maintenance Hazardous or high-value items

EQUIPMENT IN WAREHOUSES

Warehouse robots are a type of conveyor belt as is presented in Figure 5. They are highly mobile and capable of navigating themselves around the complex environment of a distribution facility. The robotics is important to implement when we are talking about large package material.

Figure 5
Example of a Conveyor in a Warehouse Facility

The warehouse management system has been develop new strategies as scanner or logistic in order to handling materials, specially moving it through the warehouse floor. This mechanism can be employed by the Radio Frequency Identification (RFID) as is presented in Figure 6.

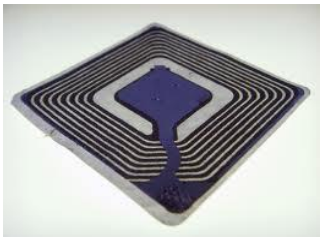

Figure 6
Example of a RFID

In the following Figure 7 it's presented the procedure of reading radio frequency identification (RFID). First the tag located in the product or pallets are read by a reader used by employees which are making a picking task. The signal information goes to a local server where enter in the planning and management enterprise system. The information is recorded and the location evidence of the products is available.

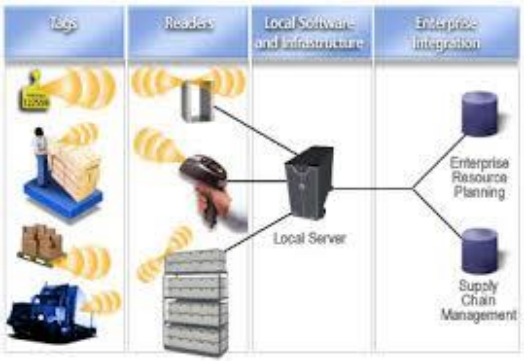

Figure 7
Functionality of Radio Frequency Identification (RFID)

Additional equipment commonly used in warehouse is the forklift as Figure 8 presented.

Figure 8
Example of an Equipment Forklift

Benefits of Warehouse Robotics are:

- Improved productivity
- Reduced labor
- Reduced Operational Cost
- Fewer safety incidents
- Faster cycle time

SHIPPING AND TRANSPORTATION QUALITY RISK MANAGEMENT

A transportation management automatized system should bring the following benefits: Real time transportation tracking, optimizing terrestrial transport rounds, vehicle road and route optimization and shipment batching of orders.

EVALUATION OF DEVICES TO MEASURE TEMPERATURE AND HUMIDITY

The evaluation of the location of measuring device inside the trailer is the key to measure the desire properties at every point inside the trailer. Association Study Full Trailer is showing in the following Figures 9 and 10. This figure shows the full trailer monitor placement strategy [6]. In Figure 10 [6] shows the pallets are loaded in pinwheels style. In Figure 9 and 10 the blue dots means monitor place at middle height and green dots means two monitor which one is place at the top and the other one in the bottom. In an empty trailer the monitoring should be arrange as presented in the following Figure, 11 and 12. The Figure 12 [6] is the empty trailer monitor placement. In Figure 11 and 11 [6] the blue dots means monitor shall be place at middle height and green dots means two monitor which one is place at the top and the other one in the bottom. The white dot means the temperature mapping study monitor.

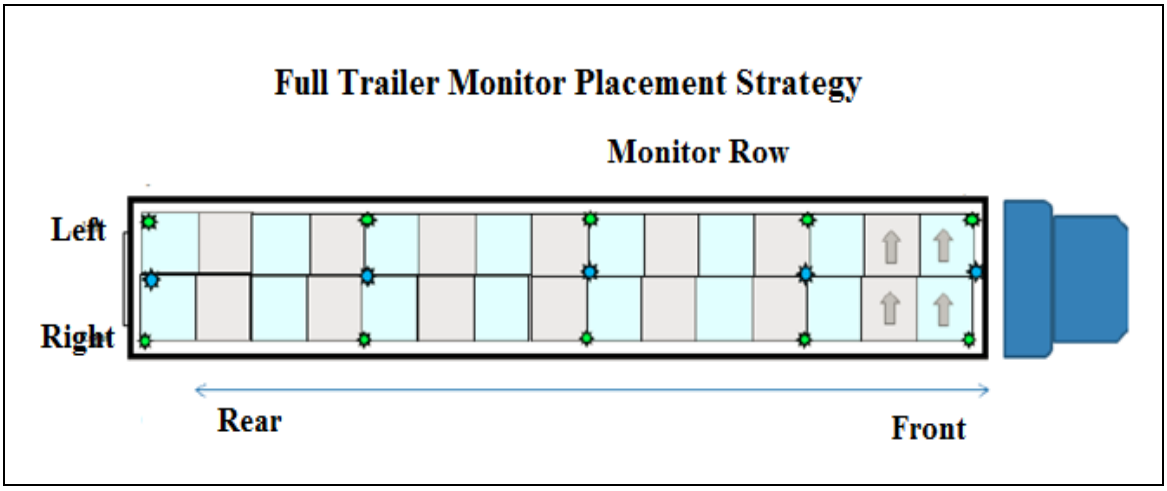

Figure 9
Full Trailer Monitor Placement Strategy

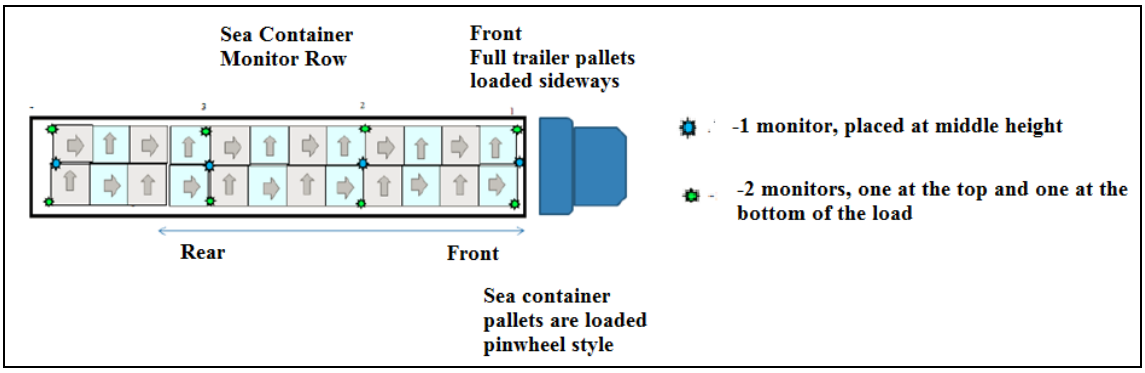

Figure 10
Sea Container Monitor Row

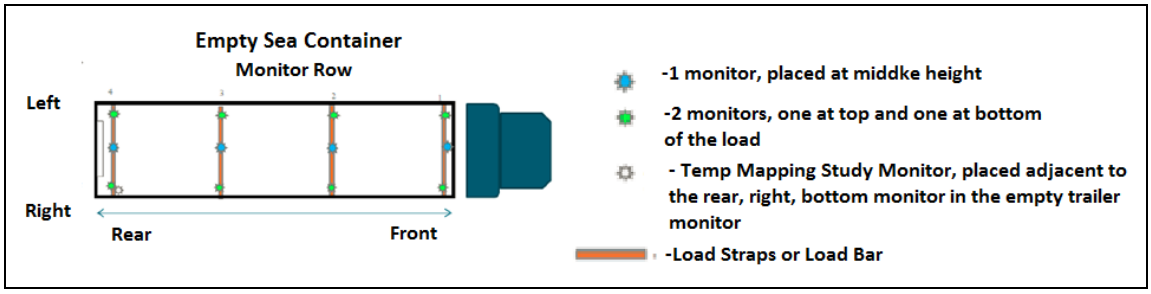

Figure 11
Empty Sea Container: Monitor Row

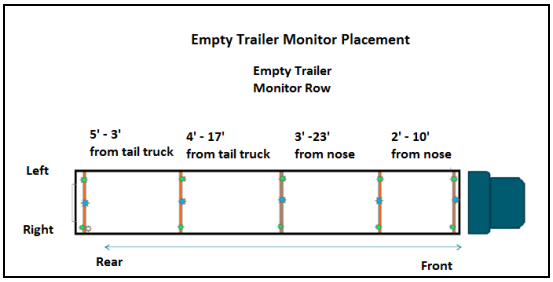

Figure 12
Empty Trailer Monitor Placement

The following Figure 13 [6] shows a closely view division of the locations of the monitors inside an empty trailer.

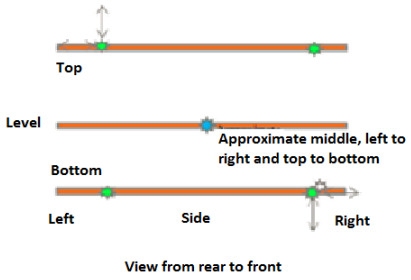

Figure 13
Different Level Inside the Trailer

In the left side of the Figure 14 [6] the star symbol shows the positions of the monitor in the full trailer. The centers and bottom monitor on full trailer will be attached directly to the product.

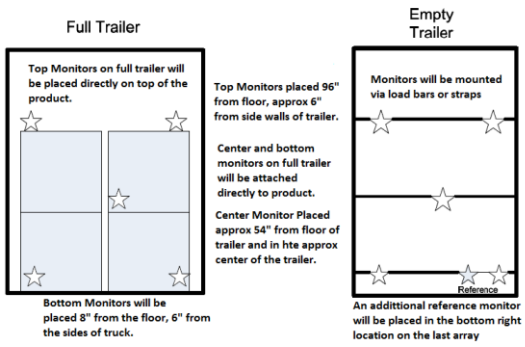

Figure 14
Location of the Monitor Inside the Trailer

In the right side of the Figure 14 shows with a star symbol the positions of the monitor in the empty trailer. The monitor will be mounted via loads bars or straps. In general the top monitor should be laced with 96” from floor and 6” from side walls of the trailer. Center monitor should be

placed 54” approximately from floor and in the center of the trailer. The bottom monitor will be placed with 8” from floor and 6” from the sides of the trailer.

STUDY

The project is designed to compare in transit temperatures between fully loaded and empty trailer and sea containers. Shipment containers will be equipped with multiple Temp Tale 4 temperature monitoring devices, placed in a pre-determined pattern.

This association study will provide two sets of key temperature statistics for each shipment. The first will compare the monitor in the lower right-hand rear location, referred to as the reference location herein, to all other locations in the empty trailer. Then all monitored locations in the empty trailer will be compared to the equivalent locations in the fully loaded trailer. This comparative temperature information can be used in analyzing Temperature Mapping Study Data.

For each shipment will provide the following two analyses:

- Within the empty container: the greatest difference in maximum temperature and minimum temperature from the reference monitor to all other monitors inside the container. These numbers provide quantified risk of temperature extremes within the empty container.
- Between the empty container and full container: the difference in maximum and minimum temperatures between the monitor at the same location between the two trucks (empty and full) These numbers provide quantified risk between the empty and full container.

The project is designed as an effective means to collect temperature data in non-temperature controlled shipments. Shipments containers will be equipped with TempTale 4 temperature monitoring devices and will be sent via Ocean, Air, Full Truckload and Less than Truckload (LTL). This study is designed to allow for up to thirty shipments on each transportation lane in the summer and winter season.

CONCLUSION

The main purpose of warehouses are picking, checking, labeling and packing goods for export. The complete operation would be enhancing if the tracking capability should be applied in the shipping and transportation phase.

Critical factors to be considered in a design of a warehouse and the shipping and transportation methods are the environmental conditions such as temperature, humidity. After evaluating this conditions an automated procedures should be implemented in order to achieve considerable conditions to preserve the products during the shipping and transportation stages. The location of the monitor instruments in the trailer is a key factor to achieve quantifiable and real data.

REFERENCES

[1] Acker, E. Warehouse. WBDG: Whole Building Design Guide. (October 2011). *National Institute of Building Sciences.*

[2] Eberle, J., O’Hearn, T., Abdallah, H., Rock, L. (2005). Guidelines for Warehousing Health Commodities. *US-Agency for International Development from American people*. John Snow, Inc.,7-22, 41, 59-61

[3] Hales, H. (2006). Put your warehouse in order. *Industrial Engineer: IE, 38*(2), 34-38.

[4] Bertorello, C. (2009). 7 Critical Steps to Planning a Cost-Effective Warehouse. *Material Handling Management, 64*(9), 35-38.

[5] Cross C. Warehouse design eliminates slim pickings. *Industrial Engineer: IE* [serial online]. October 2006; 38(10):48-49. Available from: Applied Science & Technology Source, Ipswich, MA. Accessed October 1, 2013

[6] Torres, E. (2013). *QRM Shipping Transportation*. Presentation Information presented at Interphex 2013.