Zaiko Warehouse Management Systems Application Platform

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Abstract: ***Inventory management is a discipline primarily about specifying the shape and placement of stocked goods. For any warehouse and logistics company is inventory heart of the warehouse. It is required at different locations within a facility or within many locations of a supply network to precede the regular and planned course of production and stock of materials. The scope of inventory management concerns the balance between replenishment lead time, carrying costs of inventory, asset management, inventory forecasting, inventory valuation, inventory visibility, future inventory price forecasting, physical inventory, available physical space, quality management, replenishment, returns and defective goods, and demand forecasting. Balancing these competing requirements leads to optimal inventory levels, which is an ongoing process as the business needs shift and react to the wider environment. This paper auto inventory system without human involvement auto inventory in warehouse.Auto inventory benefit is warehouse stock and operation easily conducts.***

Keywords: Auto inventory, supply chain, logistics, materials management.

1. Introduction

In a supply chain, warehousing function is very critical as itacts as a node in linking the material flows between thesupplier and customer. In today's competitive market environment companies are continuously forced to improvetheir warehousing operations. Many companies have alsocustomized their value proposition to increase their customerservice levels, which has led to changes in the role ofwarehouses.

A warehouse is a facility in the supply chain to consolidateproducts to reduce transportation cost, achieve economies of scale in manufacturing or in purchasing [1] or provide value-added processes and shorten response time [2]. Warehousing has also been recognized as one of the main operations where companies can provide tailored services for their customers and gain competitive advantage. There are various types ofwarehouses: they can be classified into productionwarehouses and distribution centers [3] and by their roles in the supply chain they can be classified as raw materials warehouses, work-in-process warehouses, finished good warehouses, distribution warehouses, fulfillment warehouses, local warehouses direct to customer demand, and value-added service warehouses [4].

Storage and inventory control include the activities related to holding materials and processes of counting and transacting the materials as it move through warehouse. Best practice attributes for following processes .1] location management and review 2] product data and special requirements 3] inventory control systems 4] Transection process 5] cycle count 6] inventory strategy.

A recent case study revealed that 40% of IT managers believe telecom asset management is an area thatneeds improvement to have a better

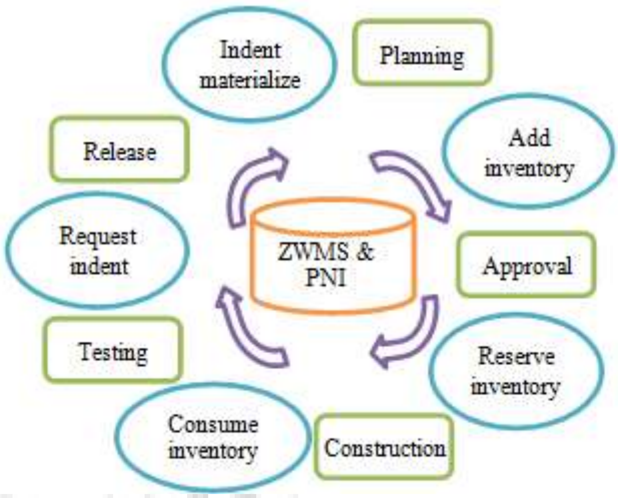


Figure 1: Enterprise Database

Network implementation processes and speed up the process.

Today, majority of Communications Service Providers' (CSP) procurement, planning and implementation teams arefunctioning in silos with their own operational activities. Each department maintains their own database and follows different methodologies to track their own departmental activities and their day to day operations.Usually CSPs planning and implementation activities will be done in Physical Network Inventory systems (PNI). Planners do not have clear visibility of the available inventory and shipment progress. It will result in delays inwork order construction due to unavailability of required inventory, lengthy procurement process, difficulty for re-plan, etc.

Therefore, it is recommended for communications service providers to have an improved PNI system that cantrack, manage and report on all their assets and operations including warehouse system.n general Communications service providers will have separate database systems to store procurement related data and GIS inventory data. ZWMS solution provides the facility to integrate the procurement data. Usually all PNI systems will have an in-built work order life cycle that is flexible enough to configure to theCSPs implementation life cycle requirements like planning, approval, release for construction and construction complete etc.,

As part of planning process, the planner will analyze the requirements and plan the site location, structure, cable and equipment etc., inventories required in PNI system. This planning is done in planning phase of work order. In this stage, ZWMS supports the planner to know the available inventory in warehouse system andprovides the facility to reserve the required inventory in ZWMS and ensures the inventory availability duringconstruction phase. During the planning stage, planner can change the plan with alternative inventory if the required inventory is not available.

During the transition from Planning to Construction, ZWMS will check the final list of planned inventories andautomatically reserve or release required inventory[9-11]. ZWMS provides a facility to raise a purchase request for the inventories which are not available in the WMS. The ZWMS will not allow the planner to transition the jobfrom planning to construction until the inventory is made available or indented. This way, ZWMS provides fullcontrol on planning till it gets roll out. ZWMS has the facilities to configure the inventory threshold values. By using the thresholdvalues ZWMS will check the availability of the inventories with respect to threshold values on a periodic basis and automatically will raise an alert / indent to the responsible authorities if any of the inventories falls below the threshold value.

Warehouse operation and inventory flow.

This application suite designed to optimize warehouse operations. These solutions manage the entirewarehouse operation cycle in a real time mode System controls warehouse personnel as well as material handling equipment, and operatively generatestasks for users based on a current situation. Leading-edge system capable of generating recommendations on the optimization of thetechnological operations in a warehouse as well asmanage personnel and material handling equipment inorder to achieve highest performance [11-15].

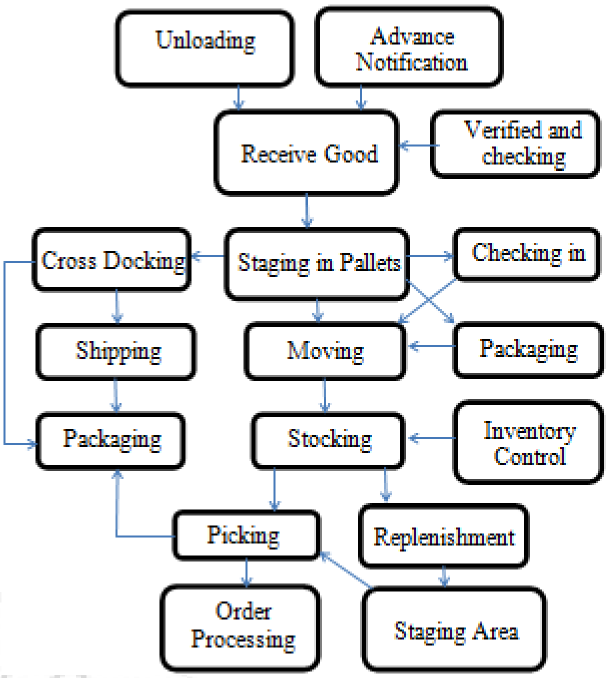


Figure 1: heterogeneous warehouses map

The Z (WMS) system eliminates the need for paper documentation.All documentation is generated, transmitted, processedand optimized in the system and transformed into precise tasks sent individually to operators' RF terminal screens.Every operation is confirmed and logged into the system bythe operator through either scanning a bar code, orentering data via the RF terminal keyboard Therefore, information on product quantity and allocation in thewarehouse is always accurate and up-to-date, so anymistakes or exceptions can be noted and immediately corrected. The objective of is automation of the entirewarehouse management cycle – from the point that goods are received at the warehouse up to the delivery ofcustomer's orders. The scope of implementations can varyfrom basic warehouse control (management system basedon paper task-lists) to a complex, full-scale warehousemanagement system in real time mode using barcode, RFdata transmission and material handling equipment thatpositions technologies and other automation meansdepending on the customers' needs[16-18].

The Warehouse Management System optimizes theput away and storage of inventory through dividing thewarehouse into designated areas and utilizing space in the most efficient way. The ability to conduct cycle counting during the regularworkday reduces or eliminates the need to shut downoperations to conduct a physical inventory count. Z (WMS) allows customers to increase quantitative andstowage data accuracy to 99.9% while reducing theduration of receiving and shipping operations by 2-3 times.

Adaptability is one of the most significant features of Z (WMS). The system can be configured in order to meet thespecific operational and business requirements of the customer[19-21]. The system is integrated with RF and barcodeequipment, electronic scales, printers and scanners. A warehouse management system or Z (WMS) primarily aims tocontrol the movement and storage of materials withina warehouse and process the associated transactions, includingshipping, receiving, put-away and picking. A warehousemanagement system (WMS) is a database driven computerapplication, to improve the efficiency of the warehouse bydirecting cutaways and to maintain accurate inventory byrecording warehouse transactions. The systems also direct andoptimize stock based on real-time information about the status of bin utilization [20-21].

Warehouse management systems can be stand-alone systems or modules of an ERP (Enterprise Resource Planning) systemor supply chain execution suite. The primary purpose of aWMS is to control the movement and storage of materialswithin a warehouse. The WMS can be deployed as a paper based, RF/wireless based or combination of both [22-25].

Warehousing takes up to between 2% and 5% of the cost ofsales of a corporation and with today's highly competitiveglobal business environment organizations are emphasizingon Return on Assets, and hence minimizing warehousingcosts has become an important business issue. Many firms areautomating their basic warehousing functions to achieve theincrease in throughput rates or inventory turns required fortheir warehousing operations to be cost effective.It is necessary to allocate warehouse resources efficiently andeffectively to enhance the productivity and reduce theoperation costs of the warehouse. One vital areadetermining the efficiency of warehouse is the determinationof the proper storage locations for potentially thousands ofproducts in a warehouse. Various factors affecting the storageassignment like order picking method, size and layout of thestorage system, material handling system, productcharacteristics, demand trends, turnover rates and spacerequirements are been extensively studied. It has beensuggested that selecting appropriate storage assignmentpolicies (i.e. random, dedicated or class-based) and routingmethods (i.e. transversal, return or combined) with regards toabove factors is a possible solution to improve the efficiency. Various decision support models and solution algorithmshave also been established to solve warehouse operation planning problems [5-8].

The use of information systems for warehouse management isstudied extensively in literature. Complexity of warehousemanagement is indicated among others by amount andheterogeneity of handled products, the extent of overlapbetween them, amount and type of technology as well ascharacteristics of associated processes. As the complexityincreases it becomes necessary to use Warehousemanagement systems for handling warehouse resources and tomonitor warehouse operations. The warehouses with a highamount of processed order lines and amount of stock keepingunits will be best supported by customized software. It isdifficult to update daily operations of inventory level,locations of forklifts and stock keeping units (SKUs) in real-time by using the bar code-based or manual-based warehousemanagement systems[26-28].

Storage systems & Inventory Control

Storage and Inventory Control include the activities related to holding material and the processes of counting and transacting the material as it moved through the warehouse. Best practice attributes for the following process groups are covered:

Location Management and Review, Product Data and Special Requirements, Inventory Control System, Transaction Processing, Cycle Count, Inventory Strategy.

All warehousing software runs on data; therefore, product and storage location data must be kept current and accurate. Product data should include all characteristics including cube data and lot/serial number information. Special requirements should also be noted in the system so that product can be directed to special storage areas.

Special storage areas may segregate items with odor transfer, fire risk or those that require temperature control. High-value product might require caged and/or controlled access storage. Best practice companies maintain all information on a single system of record and keep it current and accurate.It's often said that inventory is money; and that you should keep track of inventory as you would money. The activities and technology to maintain inventory accuracy are typically referred to as inventory control. The automated storage and retrieval system is amaterial handling mechanism which is a key element ofautomated warehouses or distribution centers. the RFID-enabled automated storage and retrievalracks as core component of the proposedwarehousing system[29-31]. The module is designed as astandardized element for manufacturing and assembly,although each module can be of different sizes and arrays in amodule can be configured easily in many different ways, i.e.,capacity of a warehouse is adjustable. In the warehouse,items are pre-loaded onto pallets named totes; totes need notbe of identical sizes. Each item in a tote (or a tote containingidentical items) is attached with an RFID tag and each item ina tote is thereafter tracked and manipulated by the developedRFID-inventory management system throughout the warehouse.

A typical RFID reader is a microcontroller-based radiotransceiver that powers an RFID tag using the time-varyingelectro-magnetic fields (EMF) generated from an RFIDantenna. Once an RFID tag is powered, it can receivecommands from an RFID reader. An RFID tag is composedof two essential components: an antenna and a computer chip.The computer chip is used to store data while the antenna allows data communication between an RFID tag and anRFID reader through a wireless signal transmission [32-36]. EachRFID tag has a unique identification (UID), which can beused to uniquely identify an RFID tagged item. The collected RFID information data by an RFID reader can be transferredto a host PC as database for data processing and storage.

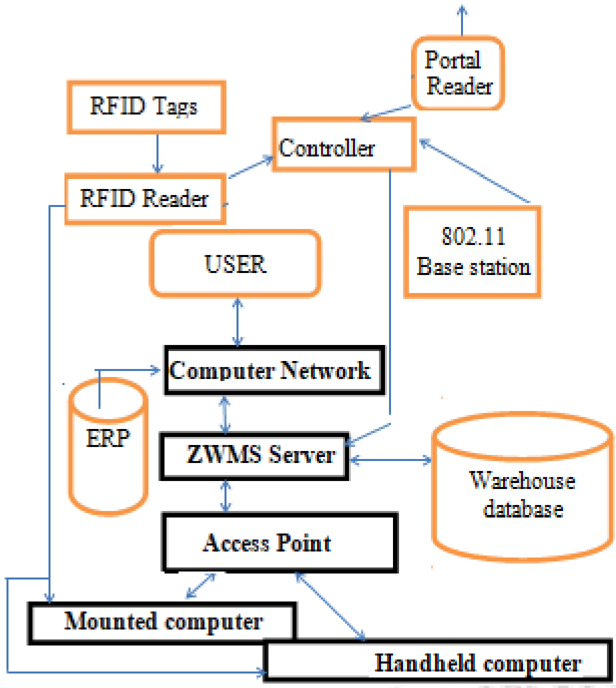


Figure 2: Zaiko warehouse management system.

Thus, the hardware of the proposed RFID-based warehousemanagement system consists of the following key elements:1) RFID Readers2) RFID tags 3) A host computertwo types of RFID tags (active and passive RFID tags)can be used depending on a range of RFID readingperformance at a location of an A/B. By using RFID tagsin the proposed automated warehouse, SKUs can bedistributed evenly and dispatched randomly at varyinglocations wherever a place is available for incoming andoutgoing goods. This design significantly facilities operations of storage, retrieval and replenishment in the warehouse shows in figure:- 2 simplified RFID inventory managementsystem for the proposed automatic warehousing system in adistribution center at where an RFID reader is mounted on the portal gate and it takes a reading of RFID-taggedincoming and outgoing goods each time when these itemsenter into or exit from the distribution center. Each pushermounted on an AS/RR also contains an RFID reader that communicates with a local controller, which transmits collected data via a middleware to a central warehousing database. The middleware is the software translation layer between an RFID reader and an enterprise system. Once anin-store item is ordered by a customer online, theRFID-inventory management system is notified after receiving the order and it checks availability from thewarehousing database, which contains real-time informationcollected by RFID readers via an indoor wireless local area network (iWLAN) through the controller. The collectedinformation data include a unique identity and a descriptionof each ordered item as well as an SKU number of the warehouse. Once an ordered item is identified by theRFID-inventory management system, a pusher is activatedby a PLC (programmable logic controller) to push the selected item in a tote onto an output conveyor. The item willthen be transported by the output conveyor and it travelsalong a guided route to a specified destination (collectionpoint) for packaging. The warehouse RFID-inventory database will then be updated as soon as this ordered item isshifted out of the distribution center through the gate equipped by the RFID-reader.

Automated material-handling activities of a pusher aredetermined by a mechanical control system that generates ademand by executing pre-defined assignment policies, which are a set of selection rules. These rules include such asavailability of the selected item, its location closest to acollection point, a shortest route for the selected itemtraveling to a specified collection point, expiry dates ofproducts if applicable and so on. If an item is selected from agroup of the same type of items stored in multiple locationsof the warehouse, the system will issue a priority based on thepre-defined selection rules to be given to the selected item toinitialize a demand to push it onto the output conveyor.Job scheduling plays an important role in efficiency andproductivity of warehousing operations. As stated previously, the proposed RFID-enabled warehousing system allows anitem to be stored randomly at varying locations wherever astorage place is available, i.e., the same type of items may have multiple locations. Hence, the developed RFID-inventory management system has capability ofidentifying a dispatched item by issuing a priority to theselected item based on assignment policies as described above. In order to schedule a job priority for the selected itemto be dispatched from the warehousing system, an algorithmwas developed to seek an optimal solution for a selected itemwhich has a priority over other items of the same type basedon variables in terms of such as expire date and a least traveltime to a specified collection point and so on.

Under thisintegrated RFID-enabled warehousing management system, customers place their orders on-line through a web-based platform and the RFID-inventory management systemautomatically checks its database in terms of availability ofeach ordered item. As soon as these available items areordered by a customer after making a payment online, the warehousing system then performs an automatic item-selection process without any human interference. [36-38]

ZWMS is an application suite designed to optimize warehouse operations. Manage the entire warehouse operation cycle in a real time mode. The System controls warehouse personnel as well as material handling equipment, and operatively generates tasks for users based on a current situation. ZWMS is based on automatic identification technologies (such as barcoding and others), the principle of mapping warehouse locations and assigning unique storage locations to inventory and remote personnel management. Every warehouse operator is equipped with an RF terminal - a mobile computer which can either be handheld or mounted on a forktruck. Tasks are automatically generated in ZWMS and are sent to RF terminal screens as a set of elementary sequential commands. Commands/ directions can also be set and sent by the warehouse manager, who may control the task assignment process. The operator confirms task fulfillment by scanning a label barcode at the processed location. IfRFID technology is deployed, task fulfillment is confirmed by scanning RF mark. Using the ZWMS your warehouse will be functioning as an integrated and well-controlled complex, bringing together all the resources and capable of interaction with other elements of the logistics chain.WMS will be a key component of the complex[39-40].

2. Functions of ZWMS

Optimization principles

- Automatic identification of loads/identity control
- Warehouse zoning
- Control operations in real time mode
- Workflow optimization
- Remote personnel management
- Authority levels and privileges control
- Labor standards
- Keep record of any event and action
- Material handling equipment control
- Routing optimization and load tracking and tracing
- Order staging by optimal vehicle routs (task interleaving)
- Graphical representation of the warehouse layout 13) System configuration
- Report generation
- System of help
- Support of RF and bar code equipment
- Integration with ERP system
- Statistics exchange
- OLAP (online analytical processing)

Inbound management

- Advanced notification
- Receive the nonstandard, unpacked product and returns
- Cross-docking

Operations on product in stock

- Automation and goods stocking and warehouse operations
- Put away and inventory storage rules
- Inventory allocation priority definition
- Inventory control
- Product age and expiration date control
- Load status control
- Load reallocation
- Sorting
- QC & quarantine
- Inventory management
- Inventory management by FIFO or by expiration date/shelf life
- Inventory by various units of measure
- Warehouse balance management/optimal safety stock level
- Stock inventory
- Physical counting
- Cycle counting
- Writing-off scrap and rejects
- Inventory update and elimination of load lost

Order processing

- Order planning
- Goods reservation/backup
- Picking
- Staging
- Reserving for special orders
- Kitting/assembling
- Wave processing
- Shipment
- Direct loading regardless of order continuity
- Prior consolidated order shipment
- Forward picking and replenishment
- Order re-planning
- Order cancellation and processing changes
- Handling exceptional situations
- Screening

Personnel management

- Labor productivity analysis
- Reports on every warehouse operation during certain period of time
- Keep record on every fulfilled task.

More available functionality

- Virtual warehouses (stocks)support
- Preparation of the warehouse for put away
- Receiving extra ware
- Receiving measuring product by parts
- Weight control
- Certification control
- Control during process of manufacturing
- Random control
- Single control
- Integration with the product manufacturing processes
- ISM (in stock manufacturing)
- Integration with conveyor (interfaces to control conveyor diverts and other MHE requirements)
- Goods compatibility control
- Handling loads of extreme dimensions
- Loads labeling
- Palletizer and Applicator handling
- Vehicle loading optimization
- Re-loading[40-44].

The warehouse is divided into specified areas according to technological operations in order to automate inbound, outbound and in-stock operations. The system enables the client to create a series of work algorithms to assign personnel in the most efficient manner, to accomplish warehousing and inventory movement responsibilities.

ZWMS controls task fulfillment through the scanning of a bar code. Storage locations/storage units, loads and vehicles are all marked with bar codes. The system supports any bar code type, and labels with internal bar codes can be printed out.
Material handling equipment and operators are equipped with data collection devices – RF handheld scanners and vehicle mounted terminals that wirelessly transmit data to the system.

The system considers many storage condition requirements while assigning product to put away. Temperature and humidity modes, product age and expiration date, vendors and suppliers, compatibility rules and many other parameters are considered by ZWMS.Through following designated put away rules, ZWMS automatically chooses theappropriate storage place for loads that arereceived and generates tasks for operators tomove the loads. The tasks are sent to the specificoperator's RF terminal screen according to thesequential elementary commands. The operatorconfirms that the task was completed by scanninga bar code. The system controls the operator'sactions to eliminate the misplacement of loads aswell as errors during order picking. When generating tasks, ZWMS considers themost optimal vehicle routs and subsequently reduces empty runs. ZWMS then optimallyassigns the appropriate vehicle to the task.The system controls the movement of everyemployee and is able to eliminate errors in orderpicking, inventory put away as well as the periodicmovement of goods in the warehouse. Information on load allocation, availability ofproducts, personnel activity and completed tasksare continuously updated in the system. A twodimensional graphic representation of thewarehouse layout is available at the warehousemanager response.

The system generates reports on current warehouse status or fulfilled operations. The reports can be printed out or sent to the client's ERP. The customer can choose the type and number of reports during the requirement specification and development stage [46-48].

Database

The system can be integrated with the following DBMS: Oracle, Sybase, MS SQL, and Postgres SQL&IBM DB2. Integration with any of the above listed DBMS allows customers the possibility to reduce totalownership costs and use customary DBMS.

3. Operational System

The system is based on Unix (Linux) platform, while clients applications are run under Windows иUnix.

Barcode technology

A label with a barcode is applied to loads. Depending on the standard, the barcode can encode anyinformation such as product profile, expiration date and others. It is used for unique identification ofthe loads. A barcode is a series of varying width vertical lines (called bars) and spaces. Barcodetechnology encompasses the symbologies that encode data to be optically read, the printingtechnologies that produce machine-readable symbols, the scanners and decoders that capturevisual images of the symbologies and convert them to computer-compatible digital data, and the verifiers that validate symbol quality. Coupled with the improvements in data accuracy that accompanies the adoption of bar code technology over keyboard data entry, bar code systems arecritical elements in conducting business in today's global economy. Tracking physical assets,inventory, and personnel with automated systems can save money and improve operations.

RFequipment

RFID systems work very much the same way as barcode systems, except that a clear line-of-sight between the scanner and the tag is not necessary, because product information is read by a wireless reader instead of scanning a label. The information that is transmitted via radio signals isable to travel through most materials. RF tag, RFID scanner and a decoding device computer) are the attributes of RFID. RFID allow for non-contact reading and are effective in manufacturing and other hostile environments where bar code labels could not survive. The technology is able to trackremote and moving objects and to encode more information in comparison to usual bar code label. Wireless networking and mobile computers are an integral part of a bar code or RFID data collection systems.

Economy efficiency

1) Integration
   Integration methodology with ERP systems was developed during numerous project implementations. ZWMS successfully integrated with SAP R/3, Axapta, 1C, Monolit, Glaktica and others.
2) Customer Relations Management
   - Eliminate non-standard order shipment, create reports of extra shipment or order return
   - Reduce expired product write off costs
   - Increase quality of services.
3) Logistics
   - Optimize warehouse inventory flow
   - Increases quantitative and stowage data accuracy to 99.9%
   - Complete control over inventory flow
   - Warehouse space optimization(increase warehouse utilization by 5 to 25%)
   - Increase inventory through-put and turns
   - Employ best put away strategies.
4) Maintenance costs
   - Material handling equipment rational utilization
   - Equipment deployment optimization
   - Reduce transportation costs (save fuel and electricity, reduce maintenance costs and extend the life of material handling equipment).
5) Personnel management
   - Increase employee efficiency
   - Eliminate employee errors and increase accountability
   - Reduce time required for warehouse processes
   - Enhance labor productivity by an average of 20%, 30%
6) Management accounting and document circulation
   - Speed up data interchange
   - Data access in real time mode
   - Reduce paper work
   - Inventory control without interrupting warehouse operation
   - Integration with corporate systems.

Advantage of ZWMS

1) Leading-edge world-wide business algorithms implementation
2) Individual approach
3) Use the most known development tools and operational systems
4) Best world-wide business algorithms implementation
5) High performance and elevated system operability
6) Advanced functionality
7) Integration with various processes and systems through using adeveloped integration methodology
8) Proven implementation technology and training methodology

9) Unified open standards
10) Unified architecture standard
11) Client-server architecture
12) Cross-plat forming
13) Modules structure
14) Scalability
15) Openness.

4. Improvement of warehouse

Measuring warehouse metrics is critical for providingmanagers with a clear vision of potential issues andopportunities for improvements. Metrics are tied directly to the business strategy and operation's success drives thefinancial results of the organization. If warehouses are goingto contribute to be a source for adding value to the supply chain then they need to measure their performance with perfect metrics.

The metrics for measuring performance in a warehouse fallinto three main categories which includes order fulfillment, inventory management and warehouse productivity.

The establishment of metrics for auditing warehouse performance and assessment of ZWMS potential as a basis for investment justification should be the first steps in any WMSproject. The identification of proper metrics andopportunities for improvement can be a preliminary justification to determine potential payback. Thefollowing metrics supplements the above process.

Order fulfillment

1) On time delivery,Orders delivered on timeper customer requested date.
2) Order fill, Orders filled completely on first shipment.
3) Rate Order, Order picked, packed and shipped perfectly.
4) Accuracy Line, Lines picked, packed and shipped perfectly.
5) Accuracy Order cycle time, Time from order placementto shipment.
6) Perfect order completion, Orders delivered without changes, damage or invoiceerrors.

Inventory management measures

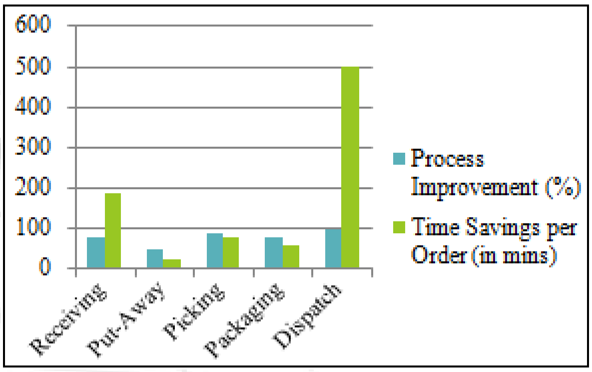
1) Inventory Accuracy, Actual inventory quantity tosystem-reported quantity.
2) Damaged inventory, Damage measure as a % ofinventory value.
3) Storage utilization, occupied space (squarefootage) as a % of storage capacity (square footage).
4) Dock to stock time, Avg. time from carrierarrival until product isavailable for order picking.
5) Inventory visibility, Time from physical receiptto customer service notice of availability.

Warehouse productivity

1) Orders per hour, Avg. number of orders picked and packed perperson hour.
2) Lines per hour, Avg. number of orders linespicked and packed perperson hour.
3) Items per hour,Avg. number of orders items picked and packed perperson hour.
4) Cost per order, Total warehousing costs Fixed: space, utilities and packed per person hour depreciation Variable: labor / supplies.
5) Cost as a % of sales, total warehousing cost as apercent of total company sales.

Performance Improvements at Warehouse after WMS Implementation

Process	Time Savings per Order (in mins)	Process Improvement (%)
Receiving	188	79
Put-Away	26	48.77
Picking	79	88.66
Packaging	58	79.09
Dispatch	504	98.02



1) Optimized processes
2) Improved supplier and customer relationships
3) Reduced operational expenses
4) Reduce plan to roll out time
5) Better demand planning
6) Transparency and visibility
7) Monitor and control the consumption of inventory
8) Alerting on short fall
9) Controls work flow based on availability
10) Facility to raise and track the Inventory Indents

5. Conclusion

As an impact of large product varieties and shortenedcustomer response times there is a greater emphasis on theability of the organizations to establish smooth and efficient logistics operations. ZWMS (Ware House Management) is the solution that enhances the existing Physical Network Inventorysystem functionality and enables the planner to choose the required inventory based on the availability instore during the planning or provides the facility to raise the indent for planning inventory.

References

[1] "Production and Operations Management: Manufacturing and Services", R.B. Chase, N.J. Aquiline and F.R. Jacobs, Eighth Edition, 1998, pp. 582-583.
[2] "Operations and Supply Chain Management: The Core", Third Edition, F. Robert Jacobs and Richard B. Chase, p 346.

[3] Maynard's Industrial Engineering Handbook, Fifth Edition, Kjell B. Landin (ed.), McGraw-Hill 2001, p G.8.
[4] "Factory Physics for Managers", E.S. Pound, J.H. Bell, and M.L. Spearman, McGraw-Hill 2014, p 47.
[5] T.C. Poon, K.L. Choy, Harry K.H. Chow , Henry C.W.Lau, Felix T.S. Chan, K.C. Ho (2009), A RFID casebased logistics resource management system formanaging order-picking operations in warehouses,Expert Systems with Applications, Vol. 36(4),
[6] Felix T.S. Chan, H.K. Chan (2011), Improving theproductivity of order picking of a manual-pick and multilevel rack distribution warehouse through theimplementation of class-based storage, Expert Systemswith Applications, Vol. 38(3).
[7] JinxiangGu, Marc Goetschalckx, Leon F. McGinnis(2007), Research on warehouse operation: Acomprehensive review, European Journal of OperationalResearch, Vol. 177(1),
[8] S.F. Wamba, T.R. Coltman, and K. Michael (2008).RFID-Enabled warehouse optimisation: Lessons fromearly adopters in the 3PL industry. ICIS Ancillarymeeting, Paris, France.
[9] Brown, S, (1997), Revolution at the Check Out Counter, Harvard Publishing
[10] Powell, W., Sheffi, Y., Nickerson, K., Butterbaugh, K., Atherton, S. (1988) Maximizing profits for truckload carriers: a new framework for pricing and operations.Interfaces, 18(1) pp 21-42, Jan-Feb 1988
[11] Smith, S. and Sheffi (1990), Y., Locomotive scheduling under uncertain demand.Transportation Research Record, 1251 pp 45-54, June 1990.
[12] Chopra, S. and P. Meindl (2000) Supply Chain Management: Strategy, Planningand Operations, Prentice Hall
[13] Christopher, M. (1998) Logistics and Supply Chain Management: Strategies forReducing Cost and Improving Service (2nd Edition), Financial Times Prentice Hall
[14] Shapiro, J. (2000) Modeling the Supply Chain, Duxbury Press
[15] Simchi-Levi D., P. Kaminski and E. Simchi-Levi (1999), Designing and Managingthe Supply Chain: Concepts, Strategies, and Cases, McGraw Hill
[16] Pil, F. and M. Holweg (2003) Mitigating Product Variety on the Supply Chain, Working Paper, MIT Center for Technology, Policy and Industrial Development.
[17] Kritchanchai, D., and MacCarthy, B.L., (1999) "Responsiveness of the order fulfillment process", International of Journal of Operations and Production Management, Vol 19, No. 8, pp 812-833
[18] Shaw, A, D.C. McFarlane, Y.S. Chang, P.J.G. Noury, (2003) Measuring ResponseCapabilities in the Order Fulfillment Process, Proceedings of EUROMA, Como, Italy.
[19] Ericson, J. (2003) RFID Rising, Line56, February 13th, 2003.
[20] Matson J.B., and McFarlane, D.C., (1999). Assessing the responsiveness of existingproduction operation, International Journal of Operations and ProductionManagement. 19 (8), pp 765-784
[21] Finkenzeller, (1999), RFID Handbook, John Wiley & Sons.
[22] Sarma, S, (2002), Towards the 5c Tag, Auto ID Center White Paper, CAMAUTOID-WH01,www.autoidcenter.org.
[23] Auto ID Center - www.autoidcenter.org
[24] Habermann, A, ed (1999), Twenty-Five Years Behind Bars: The Proceedings of the Twenty-Fifth Anniversary of the U.P.C. at the Smithsonian Institution, September 30, 1999, Wertheim Publications in Industrial Relation
[25] J.B.Hunt (1994) 1993 Annual Report to Shareholders. J.B.Hunt, Arkansas.
[26] GMA/FMA (2000), Retail Out of Stock: A Worldwide Examination of Extent, Causes and Consumer Responses, Grocery manufacturers of America and the Food Marketing Institute study. (see: http://www.fmi.org/supply/)
[27] BBC, (2003), Supermarket Tries Out Smart Tagging, BBC News, www.bbc.co.uk, 16 January
[28] IFPW (2002), FellettiSpedazzi Part of RFID Test, International Federation of Pharmaceutical Wholesalers Journal, v9, n7
[29] Hewett, P, (2002), Auto ID and Product Life Cycle Management, Master's Thesis, Manufacturing Engineering Tripos, University of Cambridge.
[30] Garcia, A, McFarlane, D, Thorne, A, Fletcher, M (2003), Auto ID in Materials Handling, Auto ID Center White Paper, CAM-AUTOID-WH017, www.autoidcenter.org.
[31] Hodges,S, Thorne, A, Garcia, A, Chirn, J, Harrison, M, McFarlane, D (2002), uto-ID Based Control Demonstration Phase 1: Pick and Place Packing with Conventional Control, Auto ID Center White Paper, CAM-AUTOID-WH06, www.autoidcenter.org.
[32] Brusey, J, Fletcher, M, Harrison, M, Thorne, A, Hodges, S, McFarlane, D, (2003),Auto-ID Based Control Demonstration Phase 2: Pick and Place Packing with HolonicControl, Auto ID Center White Paper, CAM-AUTOID-WH011,www.autoidcenter.org.
[33] Thomas, V, Neckel, W.; Wagner, S., (1999) Information technology and productlifecycle management, Proceedings of the 1999 IEEE International Symposium on Electronics and the Environment, pp 54 -57
[34] Parlikad, A, McFarlane, D, Fleisch, E, Gross, S, (2003), The Role of Product Identity in End of Life Decision Making, Auto ID Center White Paper, CAMAUTOID-WH017, www.autoidcenter.org.
[35] See www.crimereduction.gov.uk
[36] Byrnes, J., Y. Sheffi and J. Wass, (2002), AutoID: Selective or ComprehensiveSystem, AutoID Brief, MIT.
[37] Brandt, J.R., Taninecz, G.: Turning Toward Success for Automotive Suppliers. MicrosoftCorporation. 2008. [online] Retrievedfrom:http://manufacturingbenchmarks.com/mpigroup/wp-content/uploads/2012/06/AutomotiveSuppliers_WP_US.pdf
[38] Ericsson, R. et al.: From Build-to-Order to Customise-to-Order. Advancing the Automotive Industry by Collaboration and Modularity. Published by the

Consortium of the AC/DC Project. 2010. ISBN 978-91-633-6973-5. [online] Retrived from:http://www.iao.fraunhofer.de/images/downloadbereich/300/advancing-the-automotiveindustry-by-collaboration-and-modularity.pdf- 31
[39] Hebeler, P.: Achieving Automotive Supplier Excellence: Flawless Delivery Execution. Oracle Corporation. 2003. [on-line] Retrievedfrom:http://www.oracle.com/us/industries/automotive/018918.pdf
[40] Charter, M. et al.: R&D Report - Supply Chain Strategy and Evaluation. The Sigma Project. 2001. [online] Retrived from:http://www.projectsigma.co.uk/rndstreams/rd_supply_chain_strategy.pd
[41] Oughton, D.: Automotive Supply Base Roadmap. Report of a workshop facilitated byInstitute for Manufacturing, University of Cambridge. 2007. [online] Retrived from:http://www.ifm.eng.cam.ac.uk/uploads/Research/CTM/Roadmapping/auto_supply_roadmap_report.pdf
[42] Palm, D.: Strategies For The Optimisation Of Your Supply Chain: Taking An End-ToEnd Perspective To Increase Efficiency. Fraunhofer Project Centre for Production and Logistics Management, Vienna. In.: Auto CEE 08 Conference. 27.11.2008 Prague
[43] Pampillón, C.A.M.: Study of the Trends in the Automotive Sector. Master´s thesis. Luleå University of Technology, Department of Applied Physics and Mechanical Engineering,Sweden. 2005. ISSN 1402-1617. [online] Retrived from: http://epubl.ltu.se/14021617/2005/209/LTU-EX-05209-SE.pdf
[44] Project MyCar: Flexible assembly processes for the car of the third millennium. 2006.[online] Retrivedfrom:http://lms.mech.upatras.gr/MyCarImg/MyCar%20brochure.pdf
[45] Reichhart, A, Holweg, M.: Creating the Customer-responsive Supply Chain: A Reconciliation of Concepts. University of Cambridge. 2007. [online] Retrived from:http://wwwinnovation.jbs.cam.ac.uk/publications/downloads/reichhart_creating.pdf
[46] Schwarz, M.: Trends in the Automotive Industry - Implications on Supply Chain Management. Cisco Internet Business Solutions Group. 2008. [online] Retrived from:http://www.cisco.com/web/about/ac79/docs/wp/ctd/Auto_Trends_WP_FINAL.pdf
[47] SYSPRO: Automotive component industry positioning paper. 2012. [on-line] Retrived from: http://k3syspro.com/_files/6-automotive%20whitepaper.pdf
[48] Toyota Production Systems. 2012. [on-line] Retrived from: http://www.toyota-global.com/company/vision_philosophy/toyota_production_system/illustration_of_the_toyota_production_system.htm