Integrating Back-Office & Retail Store Management in ERP Through Simulation Models

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Abstract: - The paper describes shortly the architecture of a complex system for managing back office activities and store management including MRP, Demand forecasting, stock evaluation system from the logistics and financial point of view, integrated in a company ERP. Simulation was the way to properly define the most suitable algorithm for demand forecasting among the many complex combinations proposed by default in the ERP Central Component plus the ones proposed by key users. This architecture was applied in a complex retail chain involving different classes/clusters of point of sales and selling many different sorts of goods (grocery, food, clothing, electronics, home goods etc.)

Key-Words: - ERP Enterprise Resource Management, ECC (ERP Central Component), SOA (Service Oriented Architecture) Modelling, customer behaviour, forecasting revenues, Key Performance Indexes

1. INTRODUCTION

This work presents the logical and technical approach to define and implement a solution architecture for an ERP-Integrated system for store management and back office applications: the features included are devoted to managing goods in retail stores both from the point of view of quantities and values, considering all the possible phases of the process: from the order made by the store to the central warehouses (or directly to vendors), to the invoice process, passing through all stock movements available in the standard ERP functions and in customizing (goods receipt, good issues, stock transfer between stores, on-store food production, scrapping, claims and returns from customers and to vendors, and so on). The algorithms inside the material requirement planning tool for automated orders are chosen by simulation results on a baseline of historical data versus simulation output for the same period, compared with analysis and calculus technique (i.e. Mean Absolute Deviation).

The architecture proposed was challenging due to two main reasons; the first one is due to the problem size: the number of stores involved in the network is very high introducing heavy computation issues both for the application developed inside the ERP Central Component (ECC) and for the simulation model used for comparing forecasting algorithms, at the same time number of items to be managed (with a lot of management parameters to be customized store by store) can potentially generate an overload in the system control. The performance issue is a...
really important factor, since all the stores in the retail chain are supposed to process orders at almost the same time on the same items.

The second main issue is related to the necessity to design the operative procedures in compliance with company MIS (Management of Information System) and usually with ERP/ECC transactional system; this aspect introduces additional complexity not only in relation to the data availability and reliability. The retail chain object of the case study was coming from the recent fusion of different smaller retail chains, so there is a big issue for instance in batch procedures for synchronization of data coming from different legacy software, can affect reliability of data along the day or along the week, and a procedure of backup in case of a missing connection was setup (i.e. interface with a specific cash checkout counter can be interrupted, and sales data can be not available, but the proposal must be any case available based everyday). So it was fundamental to define procedures able to be implemented in the real MIS and with reasonable performances.

2. REDESIGNING STORE MATERIAL MANAGEMENT

The innovative idea proposed by the authors is related to the fact that the store drives the inventory management along the entire retail supply chain, getting the most up-to-date information related to real customer demand; therefore the proposed architecture is designed as a distributed system that allows to be easily accessible by remote users, but guaranteeing best computation performances from central servers and management optimization by central management. This was achieved by getting opportunities and identifying synergies in merging store requests.

In the presented case, the automated order proposal is applied to a store network of about 300 sites, many of which having in assortment at least 20'000 different items belonging to different types and classes: grocery and home supplies, clothing, fresh food, electronics, furniture etc. It is easy to understand that this is a very heavy computational problem; in addition it requires extensive access to historical data for forecasting, an effective GUI (graphic user interface) to be used by each department manager in the store, accessing only to authorized data but at the same time of other users, each one is allowed to “correct” order proposed by the system by introducing their knowledge and feelings. This is the reason why very user friendly interfaces for employees updating and correcting data remotely is needed, such as efficient reporting for central management and executive company control.

The system developed was developed for the requirement of a big retail company operating in the field of food and no-food retail, holding about 350 supermarkets/ hypermarkets/small city stores, clustered, but different as what concerns extension, assortment, pricing, location, typical average customers. The study and the implementation of the ECC integrated system started from some basic requirements:

- The creation of a set of tools able to manage all the aspects related to goods stock movements inside the stores (quantities and values) in order to build-up the store annual budget and economical/fiscal report (mandatory)
- the development of all the applications as centralized inside the ERP/ECC system already used for other applications by the company: the store application is in fact the front-end point collecting all the integrated information coming from all processes in the company: logistics, financial, marketing and promotional activities, etc.

The Integrated System, for all these reasons, is necessarily composed by a series of modules and functions interlaced among them:

- Order Proposal (custom MRP) for goods managed by company warehouses
- Order Proposal (custom MRP) for goods managed directly by vendors
- Administration and financial Procedures for on-store operations:
  - All types of goods waste declarations
  - Transfer between stores
  - Transfer of goods for internal on-store production of fresh food
  - Claims from customers
  - Errors from cash barrier
  - Inventory management
  - Claims from store to vendors (warehouses and direct ones)

In order to manage all these operations, the system needs the following input/output:
1. LOGICAL FLOW OF OPERATIONS IN THE SYSTEM

The order made by each store is somehow authorized by a calendar of possible transmissions set up by the logistic area (for warehouses) or by the commercial area (for direct suppliers). Each day each store finds in the proposal area only the items and the suppliers for which in that day there is the authorization for the order. The system automatically pre-proposes the quantity of each item that is necessary for covering the forecasted needs considering:

- Days in which the store is authorized to send orders and related days of delivery of goods (based on lead time of each warehouse/vendor for each store)
- Days in-between the next deliveries in which the store is opened to customers

The proposed coverage order considers:

- Minimum stock to be guaranteed for each item
- Stock at the present moment
- Orders to be delivered in the next period
- Forecast of sales in the period
- Other possible correction factors to be defined by the store (multipliers, leveling factors, extra-coverage etc.)

The calculation is the following:

\[ \text{Stock} + \text{Orders to be delivered} - \text{Forecast in the period of coverage} - \text{Minimum Stock guaranteed} = \]

ORDER PROPOSAL

The forecast algorithm has been chosen thanks to the use of a simulation model as decision support systems (DSS).
2. SIMULATION AS DSS FOR CHOSING FORECAST ALGORITHM

In order to evaluate efficiency and efficacy of different possible algorithms (ECC standards and customs), it has been developed a simulation model able to test all possible algorithms with different parameters. The data used for testing the forecasts was an historical series of demand (sales) data for 35 days in the past, plus one week to be considered as “future” (total: 42 days) on 5’000 items (basic assortment, common to all stores).

The forecast is evaluated each day for each item for the seven days forward, based on the 35 days in the past.

The evaluation of performance is based on the Mean Absolute Deviation technique, according with the standard performance indexes used in the ECC system. The data resulted as output from the simulation run are compared with the real data with the M.A.D. technique:

\[ \text{MAD} = \frac{1}{n} \sum_{i=1}^{n} |x_i - \bar{x}| \]

Through simulation it was possible to compare different algorithms (both ERP standards and custom) such as:

- Moving average on 35 days
- Average of homogeneous days in the week (without weights)
- Average of homogeneous days in the week (with smoothing weights)
- Average of homogeneous days in the week (with smoothing weights, deviations and correction coefficients)

The result of the simulation run has led to the choice of the Average of homogeneous days in the week with smoothing weights.

This algorithm is based on the historical data of past 5 weeks starting from the present date with a scheme that can be summarised as follows:

<table>
<thead>
<tr>
<th>Item.YYY</th>
<th>M</th>
<th>T</th>
<th>W</th>
<th>T</th>
<th>F</th>
<th>S</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>week-5</td>
<td></td>
<td>V13</td>
<td>V14</td>
<td>V15</td>
<td>V16</td>
<td>V17</td>
<td></td>
</tr>
<tr>
<td>week-4</td>
<td>V11</td>
<td>V12</td>
<td>V23</td>
<td>V24</td>
<td>V25</td>
<td>V26</td>
<td>V27</td>
</tr>
<tr>
<td>week-3</td>
<td>V21</td>
<td>V22</td>
<td>V33</td>
<td>V34</td>
<td>V35</td>
<td>V36</td>
<td>V37</td>
</tr>
<tr>
<td>week-2</td>
<td>V31</td>
<td>V32</td>
<td>V43</td>
<td>V44</td>
<td>V45</td>
<td>V46</td>
<td>V47</td>
</tr>
<tr>
<td>week-1</td>
<td>V41</td>
<td>V42</td>
<td>V53</td>
<td>V54</td>
<td>V55</td>
<td>V56</td>
<td>V57</td>
</tr>
<tr>
<td>Current</td>
<td>V51</td>
<td>V52</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Current day: Wednesday
Day for Item Demand forecasts: Thursday

In this case weighted average of the sales values on the last 5 Thursday per item/sales point, is applied. The weight of each date decreases in proportion to its oldness.

Forecasts for the j-th day of the week

\[ \frac{1}{5} \sum_{i=1}^{5} C_i \cdot V_j \]

In this case it was used 5 as fixed value, based on a simplified hypothesis that considers this as the regular value of corresponding sales data available on the history; this assumption improve system efficiency and it is reasonable for all the items characterized by low demand. In the case of goods with high demand rates, the relation is similar, therefore in this case in this necessary to properly compute days in which sales take place (excluding days in which the store is closed) and to evaluate (if exists) presence of in-week closings; due to this fact the fixed value is substituted by the real number n, properly computed, as real number of historical data available in the database over the last five weeks, for the corresponding day of the week needed by the forecast algorithm.

The weights are normalized in order to properly proceed in the computation by the following relation:

\[ 1 = \sum_{i=1}^{n} C_i \]

In the latest release of these algorithms, implemented for Retail ECC in continuity with previous logics in old legacy systems, the weights were predefined with the following settings, defined on the experience of subject matter experts and moving from the most recent week to the oldest:

1.0 - 0.4 - 0.3 - 0.2 - 0.1

The correction of demand is based on the mean value of sales on the corresponding days where none promotional activity was active for the item under analysis. To do so, the system is able to automatically recognise which items are subject to promotional activities in the period, if this information is stored and correctly maintained in the database (i.e. item master data, specific custom applications and so on).

AUTOMATED STORE ORDER GENERATION
3. GENERAL ARCHITECTURE OF BUSINESS PROCESSES AND OPERATION MANAGEMENT

The following processes was simulated in order to check the effectiveness of an new Automated Proposal for Orders to suppliers and central warehouses (in the following called OAP) that elaborates the quantities and is directly integrated in the company ERP Central Component (successfully applied to SAP R/3 Retail); at the same time the procedures for the Administrative Module for Order Proposal Management (AMOPM) are designed and tested with the support of simulation.

ORDERS TO DIRECT SUPPLIERS AND INVOICING

The Process includes the following steps:

(Prerequisite is the correct data entry related to suppliers in the ERP system)

- Order Automated Proposal (OAP) generates the order for each Store based on available data, with the same algorithms used for goods managed by the OAP through the central warehouses
- Each Store confirms the order to the Central Company Management system (CCMS)
- CCMS groups all the orders and check for possible synergies on supplier orders (i.e. reaching quantities for getting logistics or commercial discounts). Here is the possibility to implement semi-automated proposals on demand.
- CCMS sends to each suppliers the orders with the details for directly delivering the proper quantities to each store or for central delivery on the Central Warehouses (CW)
- The ordered quantities are confirmed by CCMS back to the Stores
- Bills of Parcel are confirmed by CCMS back to the Stores
- If needed: Claim Management
- If needed: Return of goods from Stores to CWs
- Invoice Production (extra OAP/AMOPM)

The centralization of direct deliveries from vendors includes all the items that usually are managed by CWs but eventually can be directly delivered by suppliers in correspondence of marketing or logistics opportunities.

This management change (from CWs to direct delivery) need to be defined in ERP Item Databases for each item/store entity (master data attributes).
The operational logic for direct delivery from suppliers to stores is based on the following general process:

1. **Sale Order**
2. **OAP Order Proposal**
3. **Purchasing Request**
4. **Purchasing Order**
5. **Material Entrance**
6. **Confirmed by Store**
7. **Bill of Parcel**
8. **Order Valorization**
9. **Material Return & Claims**
10. **Credit/Debit Notes**
11. **Squareness**
12. **Error on Valorization**
13. **Credit/Debit Writing Off Quantities/Values**
14. **OK?**
15. **Invoicing**
16. **Immediate Re-Invoicing**
17. **Confirmation by the Store**
18. **Store Updating**

**Operation Flow Chart**

**Inventory Decreasing Operations due to Dispersions**

These procedures are devoted to manage cases of items damaged, broken, lost or robbed inside the store, at different management levels, and with different results on final stock evaluation. They include:

- Updates on inventory level both for items managed by the OAP and by traditional ERP procedures
- Stock adjustments for Administration/financial procedures
- Report creation for item damaged and stolen for the following organizational layers:
  - Store Management Level (Summary and Detailed Reports) including just sales price for the involved items
  - Marketing Management Level (Summary and Detailed Reports) including also values of purchase and margins on goods.

The changes in inventories due to broken items and robberies (BIR) have different impact on the ERP system, since they require:

- Correction in Inventory Levels in OAP for the items managed by this system
- Recording inventory change due to BIR for administration/financial purposes, and periodic generation of an automated file to be examined by central administration, with checks on already processed records in order to avoid information duplication.
- Recording special causes of BIR (i.e. freezing system malfunctions FSM) for special procedures (i.e. administrative actions with insurances) can be activated as special inventory modifiers

**Material Transfer among store departments due to Internal Production activities**

In a huge retail store it is often required to simulate also material transfer "among Stores" and "among Store Departments" devoted to support internal production activities (i.e. delicatessen); these activities require the following procedures:

- Administration/financial File Support Generation
- Inventory Level Update for Stores and Departments
- Stock Evaluation attributed based on lot values using for instance FIFO Logic (first in first out logic).

**Stock Transfer between Stores**

The stock transfer between stores can be performed due to different motivations, and typically involves complex logistics and administration/financial procedures for properly attributing the final stock evaluation; in this case in fact it is necessary to define precisely and correctly the procedures in order to guarantee effective management. Different stores, in fact, can manage different assortments and different prices for the same items. Plus or minus value calculation in stock must be correctly assigned to the stores, and items not part of the assortment of the destination store are inhibited/rejected from the system. An operation of delivery confirmation both in inbound and outbound is
considered, transferring the stock on correct logical warehouses and storage locations step by step.

**Operations Flow Chart**

The item list with all relevant attributes and details can be downloaded into ERP database by Portable Data Collection Terminal (PDT) or can be directly inserted manually into ECC transactions by users. The main idea is obviously to use PDTs for massive transfers/updates and manual entry for checks and adjustments.

**Internal Production Transfer - Operation Flow Chart**

This procedure is the last step completing the “transfer among departments” procedure, typical from those retail stores that sale self-made products, such as cakes, delicatessen and so on. In inventory input there are items that then will be “transformed” in something different, to be sold in a different shape and with a different value. The inventory management needs to have this information to calculate properly quantity and values of the as-is situation and make correct forecasts for the future.

**Goods Return from Customers and Checkout Counter Record Correction**

These processes are not very simple to be managed due to the multiple cases of outputs at the end of whole life cycle of the goods flow, that includes, among the others, issues such as:

- Inventory level updated for OAP Managed Items and for items managed with standard/manual MRP
- Returns Management with all its final possibilities: scrapped, resent to supplier, blocked in quality control, checked/repaid and re-sold, gifted to non profit associations etc.
- Corrections to checkout counters errors, that can be made in different ways depending on the mistake nature.

**Inventory Store Check for Material managed by ERP**

This procedure corresponds to the inventory management activity for checking and updating storage levels regarding each single item controlled by the ERP/ECC, both the ones managed with the new MRP custom solution both with the traditional/standard procedures (if existing); the inventory check procedure applies the following policies:

**Inventory Store Check Procedure**
Claims and Material Return

The flow chart for operations in this case is based on team activities devoted to design administration (financials) and logistics procedures, and includes different phases:

- Confirmation (or not acceptance) of the Bills Parcel
- Claim Management
- Materials Return Management
- Invoice Production (extra OAP/AMOPM)

Claim Management

Claim Characteristics:
- **48 hours from delivery date for grocery**
- **24 h from delivery date from fresh food**
- Before Promotion Start Date for Promotional First Lot Delivery

Motivation:
- Based on Administrative Templates
- Distinction between Breaking due to transportation or due to handling

Goods Returns Management

Return Characteristics:
- **48 hours from delivery date for grocery**
- **24 h from delivery date from fresh food**

Motivation:
- Based on Administrative Templates
- Distinction between Breaking due to transportation or due to handling

Value of Inventory Changes for Store Budgeting

The main target for this new integrated solution is to develop a Knowledge Management System for consolidating store budgets by dynamic management.

This goal is defined as Credit/Debit Accounting and it is developed by a real time calculation of the stock evaluation going in and out from the stores.

RECENT ADVANCES in COMPUTER ENGINEERING and APPLICATIONS
1. CONCLUSIONS and DEVELOPMENT

This work proposes a general architecture for managing store operations in retail networks: a complex logic implemented inside company ERP generates automatically store requests based on historical data and updates in real-time. A simulation model has been developed to properly define the general architecture of the demand forecasting system and the procedures were the result of a business process reengineering made by the solution architects, i.e. the authors.

The authors implemented in fact a tailored solution for a large retail company involved in distribution of various classes of goods, from grocery to fresh food, from clothing to electronics. This architecture can be adapted to other different business situations, both companies operating over a big logistic network, both medium size companies with a smaller, simplified series of processes. The new challenge would be to apply the same architecture in a luxury fashion retail chain.

References:


