Integrating Supply Chain Modelling to Deliver Effective Fulfilment

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Introduction

Within the overall scope of the supply chain, there are a number of well established techniques and products that address specific areas, but the internal operation of the distribution facility has been a notable omission. This paper explores an approach to optimising the warehouse operation, in terms of product allocation to storage and picking methods and appropriate inventory levels, and identifies some of the benefits that can be achieved through this.

A typical warehousing operation will house a dynamic range of products. As a result of promotions, new product introductions and product deletions, these are constantly changing.

The approach described allows managers to:

- Allocate storage and picking media to best effect across the current product range.
- Understand capacity constraints in terms of their existing layout.
- Understand the “ideal” balance of equipment for their operation.
- Quantify and assess the costs of handling each product code in the warehouse over a given period.

The technique can be applied to existing facilities as well and new site design.

Background

The traditional focus of supply chain modelling techniques has been aimed primarily at developing network infrastructure, to establish the optimum number, size and location of distribution facilities.

Applications such as inventory modelling and forecasting software have been utilised extremely effectively to reduce the levels of inventory needed to achieve the service levels dictated by customers.

Simulation tools have been applied in many instances to assess designs or processes, for example, to establish the expected picking performance for a range of alternative picking process methods.

In a distribution operation, the variability of data is substantial. The effect of promotional activities, customer credit terms and financial reporting can result in significant peaks in activity. Changes to product ranges may mean that a distribution operation is handling products that were never envisaged at the planning stage.

Against this background, ensuring that storage equipment and picking layouts are operating at optimum efficiency is extremely difficult, but highly beneficial.

There are two levels of application of the various tools and techniques within the supply chain, as indicated in the figure below.

Strategic Modelling

Supply Chain Modelling	Inventory Management	Operations Design and Planning
Network Modelling Geographical modelling Mapping	Forecasting Statistical Analysis	Layout Design Tools Static Simulation Dynamic Simulation

Tactical Support Tools

Distribution Execution Support	WMS Software	Operations Execution Support
Vehicle Routing Scheduling	Support functionality e.g. Slotting Labour planning	?

Figure – Functional Areas of Traditional Supply Chain Modelling

The key to the success of these techniques is the level of detail of the data and how it is used within any model. The challenge with all modelling techniques is that they rely on historical data, and combine this with assessments of what future data may look like.

For strategic modelling, the impact of variability of data is relatively low. The techniques established are appropriate because of the nature of the data that is used to drive results. Within this data, there are certain assumptions or trends that can be demonstrated. For example, it is unlikely that variations in demand at a product code level would cause a company to review its logistics infrastructure, so summary of demand can be used to develop alternative network solutions with satisfactory results.

The tactical level of modelling supports execution of effective operations, and includes vehicle routing and scheduling, and the optimisation algorithms provided as functionality within some WMS packages, e.g. slotting, labour planning.

In other areas, there is a significant gap in modelling capability. A set of tools is required that allows operational analysis to be performed effectively at regular intervals.

In warehouse operations, the dynamic nature of demand profiles provides a further challenge in that general trends may not be relevant. Any change in trend can have a dramatic impact on process design and the suitability of particular equipment types.

A failing of the modelling techniques applicable to distribution centre operations is that they are not fully integrated to the complete process chain. For example, the product code parameters used by industry standard inventory management software include supplier lead time, minimum order quantity, reorder point, unit cost etc.

These parameters take little or no account of the profile of order demand, i.e. whether the product is ordered singly, in units of 5 or as full pallets.

Integrating Operations Modelling Approach

To integrate operations modelling effectively, the key areas that need to be combined are: inventory levels and resupply quantities, and the unit load formats and storage media used in the distribution centre. As these factors are linked, we have developed the approach shown below, in order to reduce the number of variables under consideration:

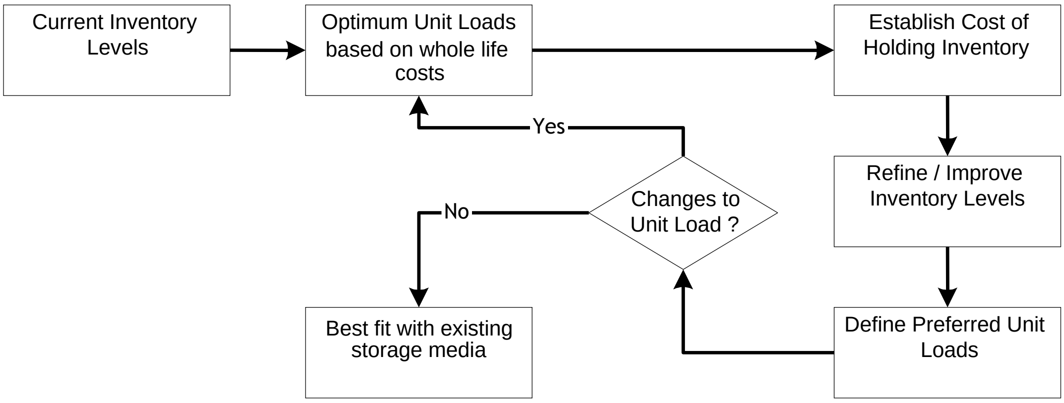

Figure – Integrated Modelling Approach

In order to understand how this approach operates in practice, it is appropriate to consider each element in turn. The assumptions at each stage, and the calculated outputs are described in more detail below.

<u>Current Inventory Levels</u>

Current inventory levels for each product code are used as the starting point of the process. This has a number of benefits.

- These inventory levels represent the immediate challenge of the operation. When presented with the modelling output, the local management team will be able to validate the results, and relate more sympathetically to any recommendations.
- The implementation of any results or recommendations developed at this early stage is not dependent on other initiatives that may lie outside the management team's direct line of responsibility.
- The modelled inventory levels provide a clear assessment of the inventory reduction that can be achieved on a product by product basis, with an associated cost saving attributable to this exercise. It is

appropriate to keep management focus on specific elements of cost reduction, identified separately, as this allows the larger prizes to be taken first.

Optimum Unit Loads and Storage Media

To establish the optimum unit load and allocation of storage media, we have developed a model to calculate the true internal operational cost associated with processing each product code, taking into account the whole life activity, as shown below:

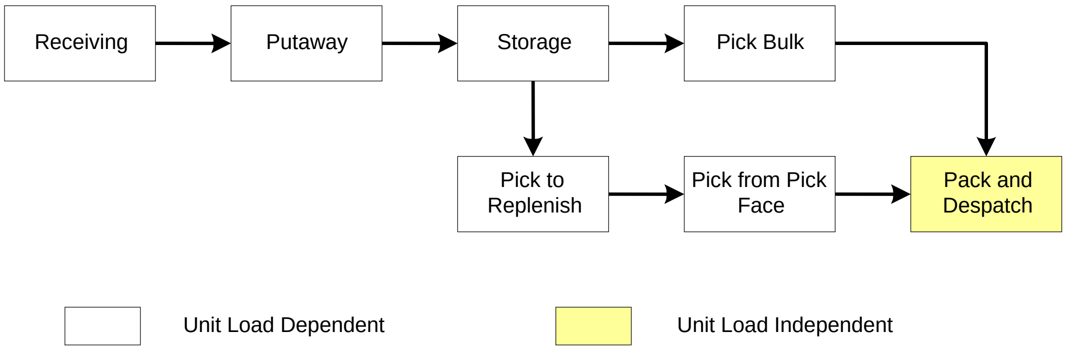

Figure – Process Activities within Fulfilment Operation

The model uses demand data at order line level for an appropriate sample period, to collate the demand for each product code.

In a standard distribution centre operation, there are a number of layout design options for bulk storage and for picking. For example, carton live storage is widely used as a configuration to deliver highly productive picking. In general, this would be installed in conjunction with some form of palletised bulk storage, in either a narrow or a wide aisle format. Across the range of products, there will be some which are best suited to being stored in the pick face only, (i.e. with no reserve inventory) and others that are appropriate for reserve locations only.

The model recognises technology solutions that are set up according to each project application. These can extend to the full spectrum of handling technologies if the objective of the exercise is to develop green field solutions. Alternatively, the selection can be restricted to the technologies that are applicable to the current distribution centre configuration.

For each product code, the model calculates the total activity required for the processes identified in the figure above, against alternative unit load formats.

By assessing the physical dimensions of the product, the model establishes the number of units that can be stored against a given unit load format, provided that the unit load dimensions are compatible with the physical dimensions of the product. In addition, specific storage needs can be accommodated to constrain the selection of appropriate storage types. For example, this would be applicable to hazardous, sensitive or high value products.

For each unit load format the model derives the resultant activity requirements. This includes the number of receipts, putaway and storage moves, and the number of replenishments required to replenish picking stock.

In addition to physical moves required, the model calculates the number of unit loads required to accommodate the inventory holding that has been specified by the customer.

These calculations are processed for each combination of bulk reserve and picking location configuration options, as demonstrated in the example shown in the figure below.

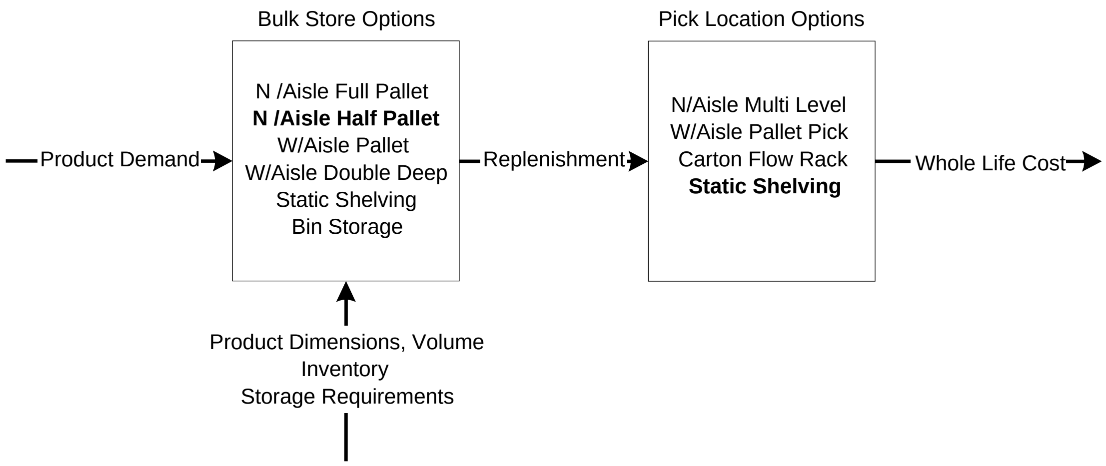

Figure – Assessment of Combinations of Storage Techniques

After these calculations have been performed for each combination of storage technologies, three elements of cost have been established:

- Storage cost
- Replenishment cost
- Picking cost

Storage cost includes the following items:

- Storage requirements, including equipment cost, and facility cost.
- Expected productivity, for receiving, putaway and retrieval, with resultant cst.
- Handling equipment requirements, with an associated cost of equipment.

Replenishment cost is calculated from the number of replenishments required against the demand for the unit load size, and includes:

- Expected productivity for replenishment of the pick face, with resultant cost.
- Handling equipment requirements, with an associated cost of equipment.

Picking cost includes an allowance for the density of storage within a pick face, and the impact on productivity, and incorporates:

- Pick location requirements, including equipment cost and facility cost.
- Productivity and labour cost.
- Picking equipment requirements and cost.

In terms of practical application, these calculations are performed for a range of between 5 and 10 bulk store options, combined with between 10 and 20 picking location configurations. The model does not attempt any optimisation, but selects a unit load and storage media based on the lowest whole life cost. Therefore, for an application with a product range of 10,000 individual codes, the model may calculate 500,000 separate permutations of storage media.

An example of the model output is shown below. This demonstrates the yearly cost of processing a specific product code, which in this example has been allocated both pick and bulk locations.

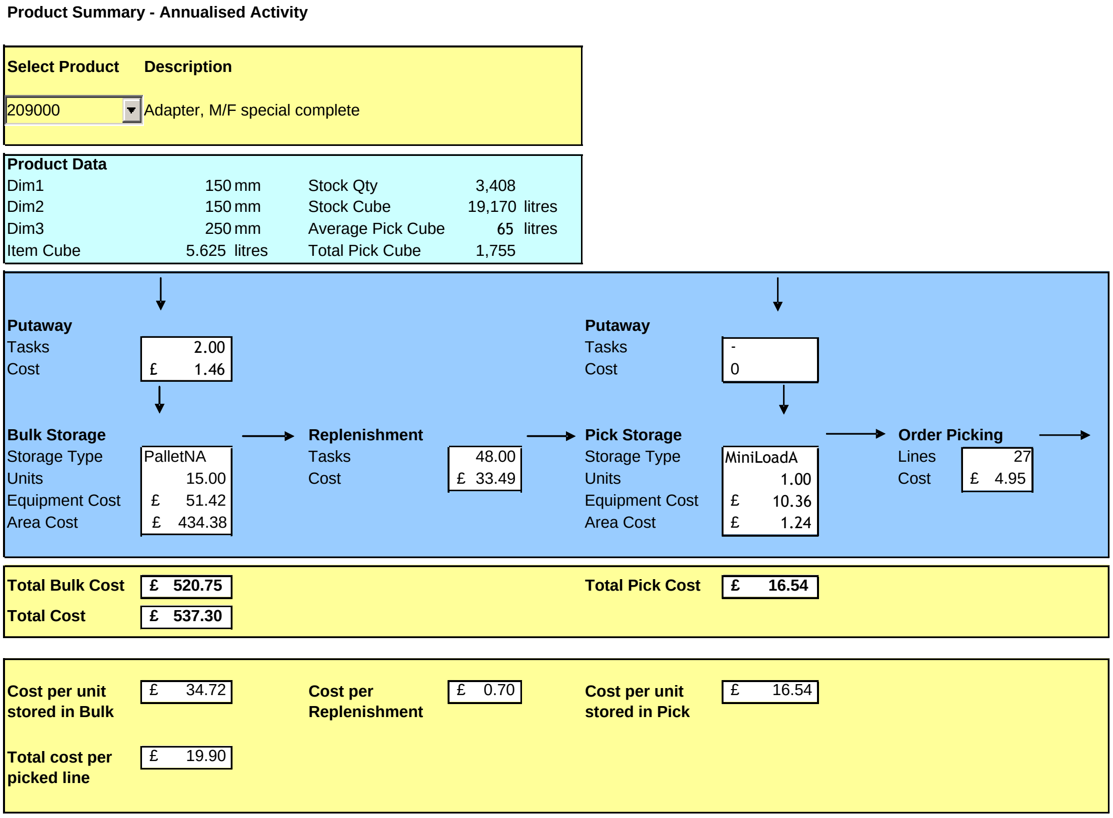

Figure – Example Model Output

At this stage of the process, the model output can be used to validate the allocation of products to unit load formats or storage media types within the existing configuration. The benefit of making any changes can be identified by comparing the cost of the current configuration of a product with the cost of the format calculated by the model.

Benefits can be achieved quickly through re-allocating products to suggested unit load formats, without any major restructuring cost.

Establish Cost of Holding Inventory

One of the key data feeds from the process of storage allocation is the cost of holding inventory. This is expressed in terms of facility and equipment cost, in addition to the finance charges.

These three parameters are now used to establish the optimum inventory holding, taking into account the product demand.

Refine / Improve Inventory Levels

Modelling of the inventory levels uses the order line data to establish safety stock, maximum and minimum levels to cover the demand variability. Product parameters such as minimum order quantity, unit cost and order lead time are used to ensure that the calculations are based on realistic and practical performance requirements.

The model maps current inventory performance of individual product codes. This is extremely useful in identifying opportunities to improve performance through the procurement and supplier management functions.

The example chart shown below indicates the actual performance for a particular product code over a sample period. This chart identifies the demand, on hand inventory, pipeline inventory and ordering and receiving patterns for a sample period. Current system parameters (maximum and minimum inventory levels and reorder point) are shown on the graph for guidance.

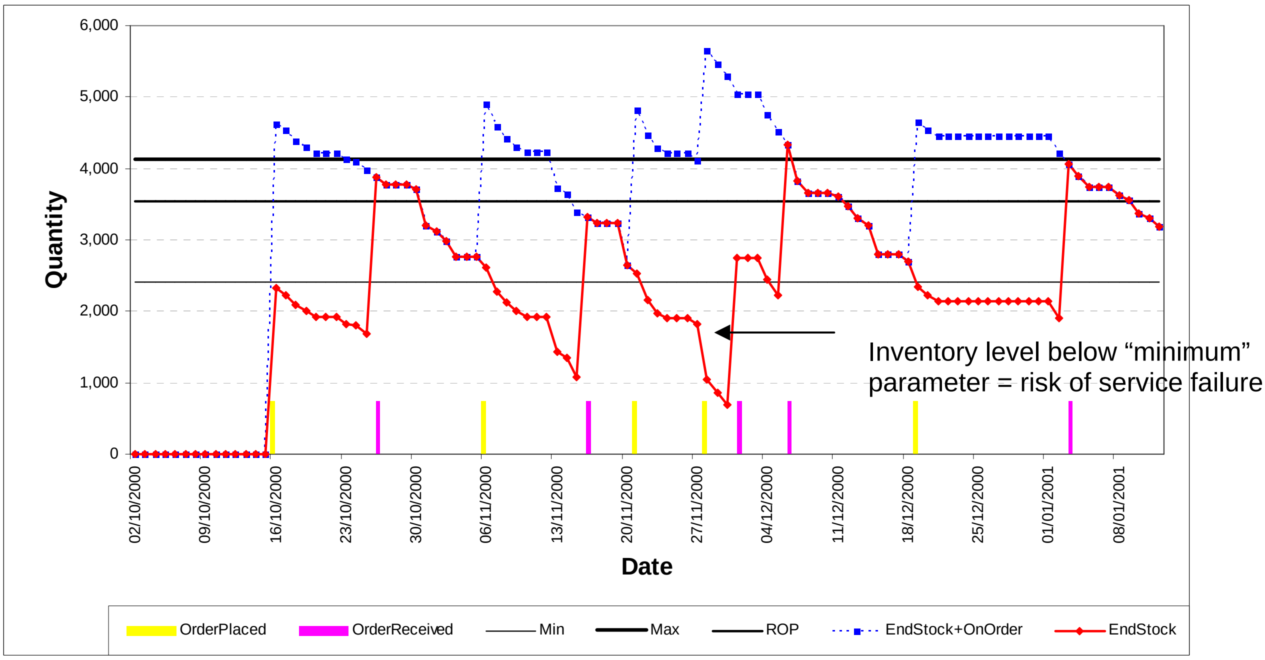

Chart - Graphical Representation of Inventories and Transaction History by Day

In addition to the above graphical representation, the model provides summary statistics against specific KPI’s, such as supplier lead time, forecast accuracy, and forecast versus average purchase order quantity, as shown below.

External Orders Placed		
Orders Placed in Period	5	
Stock in Pipeline @ PO Placement	**2,632**	
Max Stock	4,135	
ROP	3,534	ROP Max Zone
ROP - Sales in Review Time	2,693	ROP Min Zone
Min Stock	2,406	
Actual Product Leadtime	**11**	
Forecast Product Leadtime	6	
Days Variance	5	
Percentage Variance	177%	
Percentage of Order QTY within LT	0%	
Percentage of Order QTY on LT	0%	
Percentage of Order QTY over LT	100%	

Average PO QTY	**2,300**	
Estimate Size @ ROP	601	Max - ROP
Forecast PO Size (Max - Actual ROP level)	1,503	
Actual Sales in Actual Leadtime	**1,887**	
Forecast Sales in Forecast Leadtime	721	
Actual Sales in Forecast Leadtime	1,068	
Forecast Sales in Actual Leadtime	1,274	
Accuracy of Sales Forecasting	162%	
Stock Out Occurrence in PO Leadtime	0%	
Forecast Sales Per Month	**2,602**	
Forecast Sales per Day	120	

Chart – Example Summary Statistics / KPI’s from Transaction Model

The KPI's highlight those areas where actual performance within the supply chain is not consistent with the expected performance parameters.

In this example, the expected lead time is 6 days, whereas the actual lead time is 11 days. In addition, actual sales exceeds forecast. Whilst there have been no service failures on orders placed within the sample period, the inventory has been significantly below minimum levels, and true demand may not have been satisfied.

Define Preferred Unit Loads

The model establishes suggested optimum inventory levels, based on the parameters of the product, the demand and the cost of holding inventory. From these calculations, it suggests unit load formats for each product code.

Compare Unit Loads

The chart below shows the two streams of modelling, and the evaluation that each stream performs to establish the suggested unit load for each product.

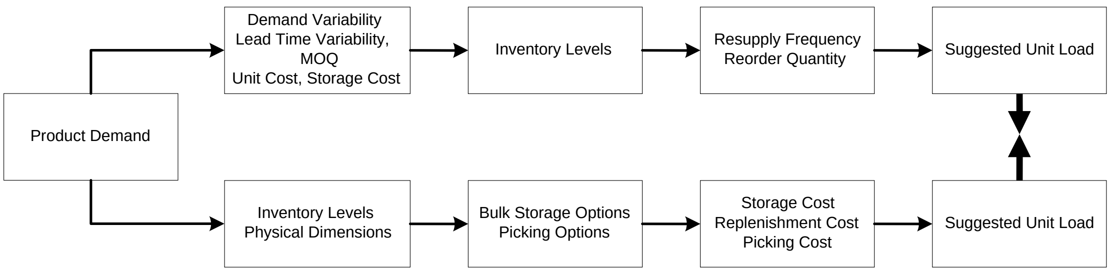

Figure – Inventory and Storage Modelling Streams

For a large number of products the unit loads derived from each stream will be consistent. There will be some products for which the two calculations have not resulted in the same suggested format. This will arise where there is significant variation between actual and calculated inventory holding.

In these cases, we perform a second iteration of the unit load optimisation. This iteration uses the theoretical inventory level for each product code calculated from the model, as opposed to the current actual inventory. It is worth noting that this may not always decrease.

In terms of sensitivity, the impact on inventory levels of slight adjustments to the cost of holding inventory will be minor. Likewise, minor amendments to suggested inventory levels will have little significant impact on the unit load allocation.

Existing Storage Media

At this stage of the process, the model has established for each product code:

- Suggested inventory levels, compared with actual.

- Resupply quantities, versus current.
- Proposed and current unit load.
- Storage formats for bulk and picking.
- Cost of operation for each product code.

Products that have inconsistencies between the current and optimum formats can be easily identified from this schedule. This allows the management team to focus on those products with the most significant benefit, and supports implementing changes to processes and procedures to deliver quick, tangible results.

Practical Application

The model provides an effective tool to allow operational management to address the dynamic nature of product demand characteristics in a regular, controlled manner. In an operational application the results can be assessed and evaluated quickly, so that a process of continuous refinement and improvement can replace occasional step changes. In this context the modelling approach is well suited to all organisations that operate facilities performing order fulfilment.

The approach delivers the most significant benefits to companies or operations with a large number of products with a diverse range of physical characteristics, and a variety of demand profiles. This represents a challenging environment in which to implement effective inventory management and efficient fulfilment operations, because of the work involved in undertaking the traditional supply chain analysis across extensive product ranges.

Case Study Examples

There are a number of practical applications of this integrated operations modelling approach, as follows:

- To increase storage efficiency and labour productivity within existing facilities.
- To evaluate the most appropriate and cost effective use of capital equipment to increase capacity within a facility.
- To establish the storage requirements for a “green field” solution, including the evaluation of a wide range of technology applications.Three case study examples demonstrate the practical applications described above.

Case Study 1 - Improving Existing Operations

This project was undertaken for a manufacturer, with facilities across Europe. The project focussed on three distribution centres in Europe (France, Germany and Italy), each operating at capacity in terms of throughput, with resultant inefficiency.

The company has a product range in the region of 3,500 individual products, and supplies own brand as well as own label goods. The majority of products are supplied to each distribution centre from in house manufacturing facilities.

The products range from small items stored in shelving through to large oversized items that are heavy and awkward, and can be prone to damage.

The modelling exercise was carried out in conjunction with a benchmarking study, to identify and assess the opportunities for improvement within the operation, and to highlight key bottlenecks to remove inefficiency.

The charts below from the model provide examples of the profile of inventory held within the facilities. Similar effects were observed across each location.

The first chart displays the inventory cover provided by a full pallet of a product. It records the number of products with full pallet inventory, and the number of products with part pallet inventory against each demand cover band.

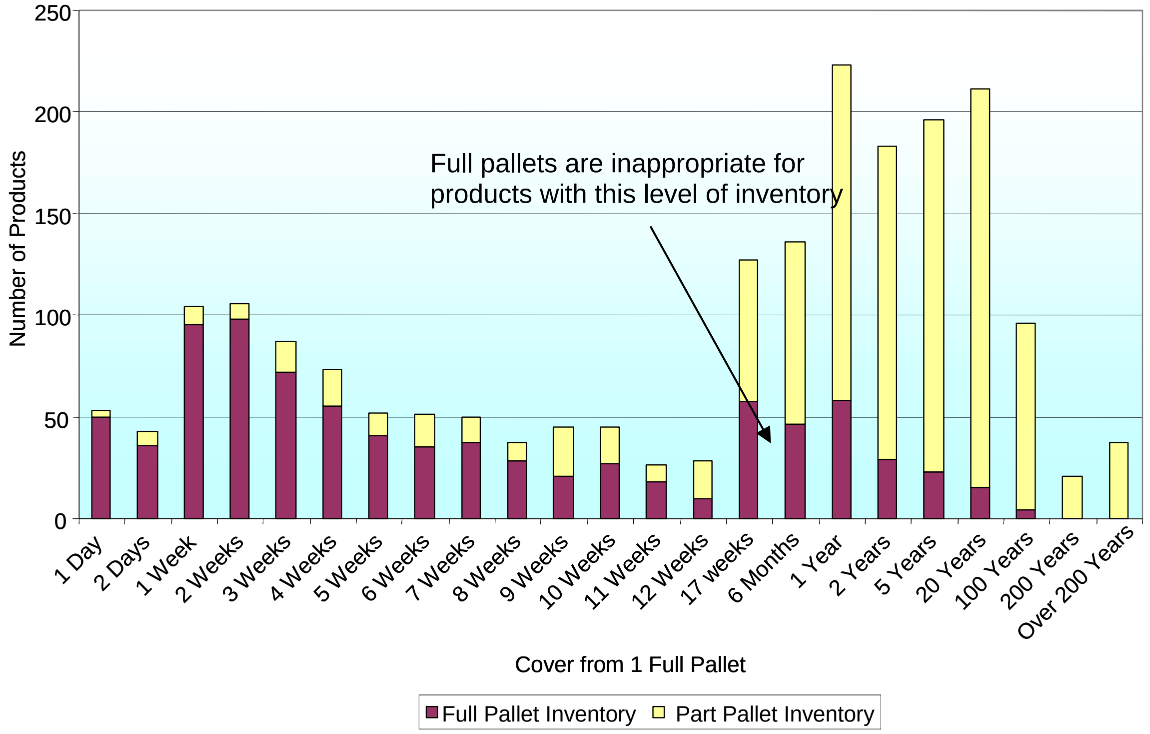

Chart – Inventory Cover and Unit Load Format Distribution

In the chart above, the anomalies in unit load format can be seen clearly when compared to the inventory targets with which the company operates. In the example data set, where a pallet represents up to 6 months' of inventory cover, nearly 50 products have inventory held in full pallet quantities.

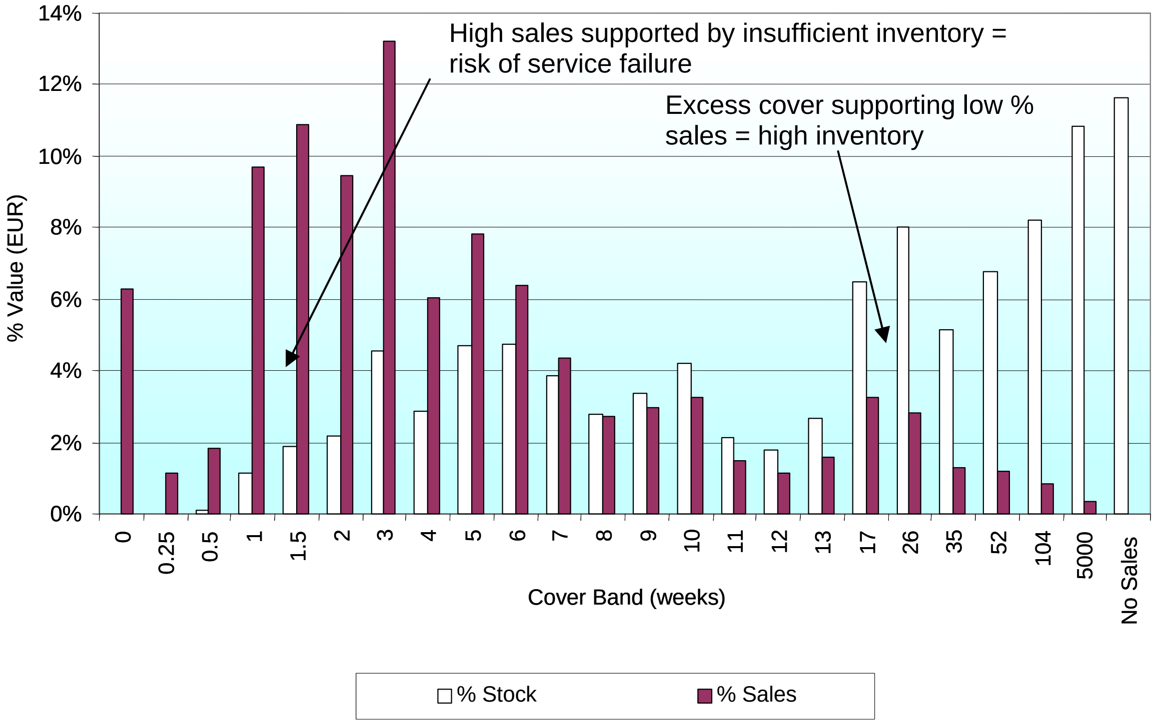

Chart – Inventory and sales disposition by inventory cover band (weeks)

The second chart displays the stock disposition across similar bands of inventory cover, comparing the percentages of sales and stock corresponding to each band. In this example location, the average inventory holding was 7.4 weeks. As a high level figure, this could be reduced, but the global nature of this indicator obscures a more complex picture.

This chart shows the high level of inventory absorbed by products that deliver very little in terms of sales contribution. In addition, the risk of service failure for some of the key products is clearly demonstrated. This is a good example where the model will suggest that inventory is increased above current levels.

The key issues within these operations were: inventory holding, space utilisation and labour productivity.

An indication of the results from the study of these three locations is shown in the table below.

Measure	France	Germany	Italy
Inventory Reduction (by Value)	22%	31%	37%
Volume utilisation increase within warehouse	32%	16%	41%
Labour productivity improvement	81.5%	38.9%	86.2%
Contributed by:			
Reduction in lines received			
Reduction in putaway moves			
Improved picking productivity			
Increased full unit load handling	35%	25%	37%

Case Study 2 - Increasing Capacity

The company has an extensive range of over 30,000 products, including many customer specific special order products. The project focussed on the utilisation of the single National Distribution Centre (NDC) that supports a network of regional branches.

The key issue for the project was the high level of occupancy of the NDC. The business had undergone substantial change in both throughput and the product ranges handled.

The storage equipment layout within the NDC was configured to use three main storage formats: pallet locations, shelving and tote bins. Before the project commenced, the company's operational management team had a very clear view of the preferred plan to improve capacity, and were seeking to confirm a proposal to introduce additional full pallet positions in the facility.

The requirement for the project was to understand the options to improve storage capacity within the NDC, and the associated capital expenditure requirements.

The chart below identifies the profile of locations suggested by the model, expressed in terms of volume. This tracks the cumulative product range from the smallest inventory volume through to the largest.

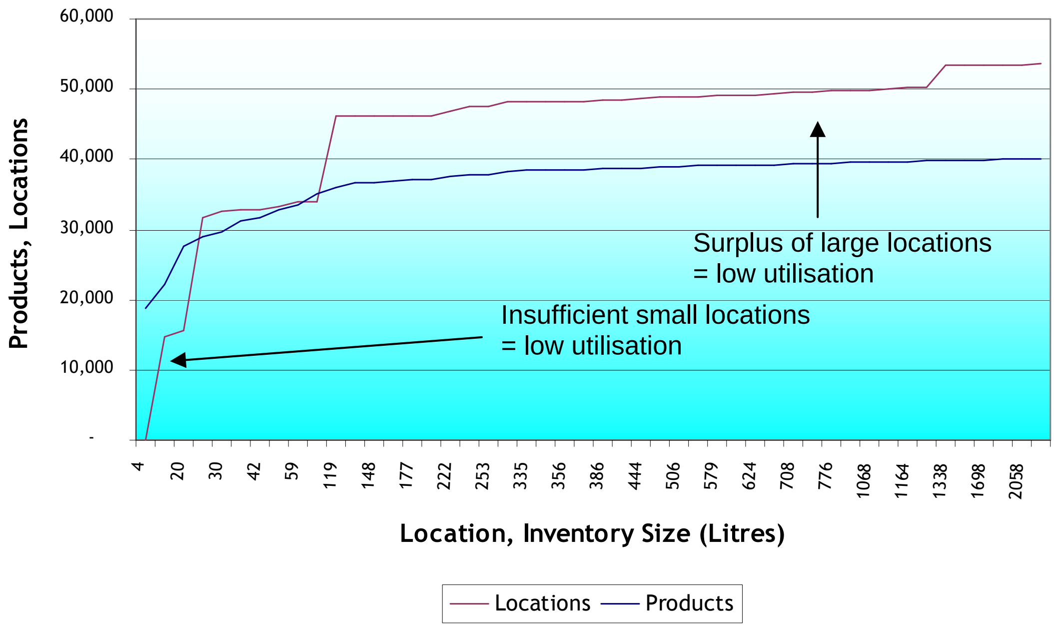

Chart – Cumulative Inventory and Storage Location Volumes by Size

The chart records the cumulative profile of inventory locations provided by the current storage configuration. This highlights two main areas of concern. For low volume inventory products, there are insufficient storage locations of the appropriate size forcing smaller products into larger volume storage locations. The utilisation of each location at this end of the profile is low. For larger volume inventory products, the location sizes provided are considerably in excess of capacity requirements, resulting in low utilisation.

The chart demonstrates quite effectively the requirements for the facility. The solution lies in the provision of additional smaller locations. These will be better utilised, releasing additional full pallet locations for larger inventory products.

In this case study, we used the model to develop alternative solutions to provide additional capacity, and to identify the incremental benefits of each element of storage. The summary results identified the following optimum improvements:

- A capital expenditure of £76k to achieve a capacity increase of 31%.
- Further expenditure of £169k to achieve an additional increase in capacity of 26%.

The time phasing required for these developments is shown in the chart below.

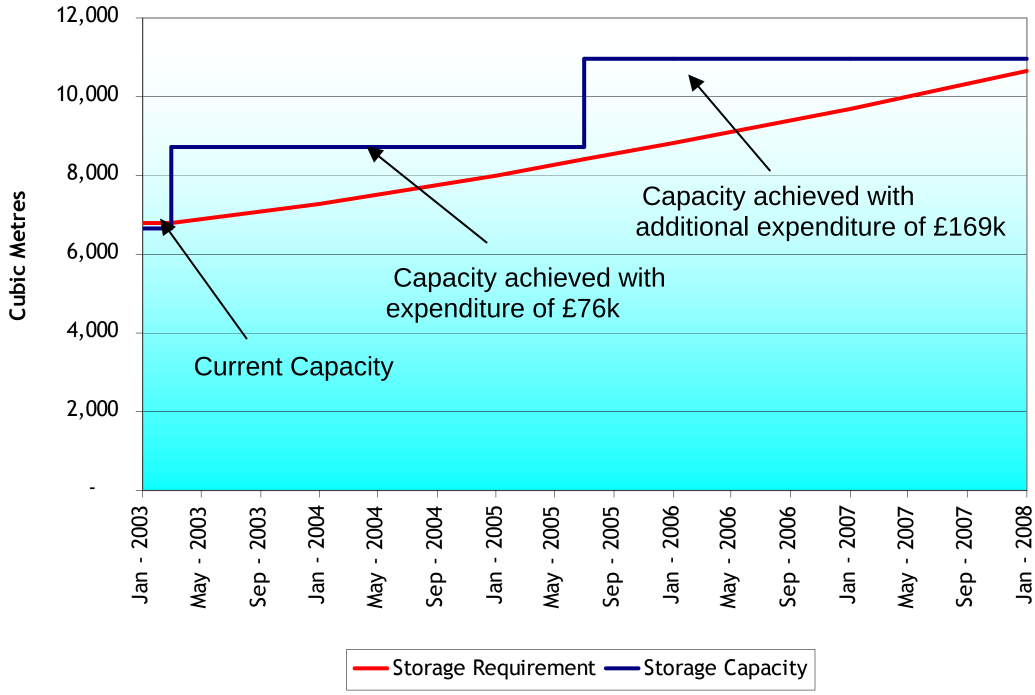

Chart – Time Phasing of Storage Capacity

This shows the level of improvement delivered through the project. Through the selection of storage media and unit loads appropriate to the product range, the life of the NDC has been extended by 5 years. In addition, the customer has benefited from a phased expenditure programme, so that surplus capacity is not created before it is required.

Case Study 3 - Designing New Facilities

This project considered the amalgamation of a number of distribution centres into a single UK location. At that time, each distribution operation serviced a particular sector of the market or a specific range of products.

In this case study there was a significant number of options for materials handling technology that could be applied. The model evaluates the application of technology options on a product by product basis, to provide a clear understanding of the requirements for the solution, in terms of:

- Equipment technology types and quantities
- The products allocated to each technology option to deliver an optimum solution.

In this example we developed 22 alternative types of media for storage and handling which covered the full range of technology from automated and manual miniload systems, vertical and horizontal carousels, through to alternative formats of pallet racking for the larger and higher inventory products. A similar range of options were developed for the picking elements.

The model allocated each of the products to 5 media types for bulk storage and 10 formats for picking (including 5 separate tote bin sizes). The resultant allocation of products to each media type for picking is shown in the chart below.

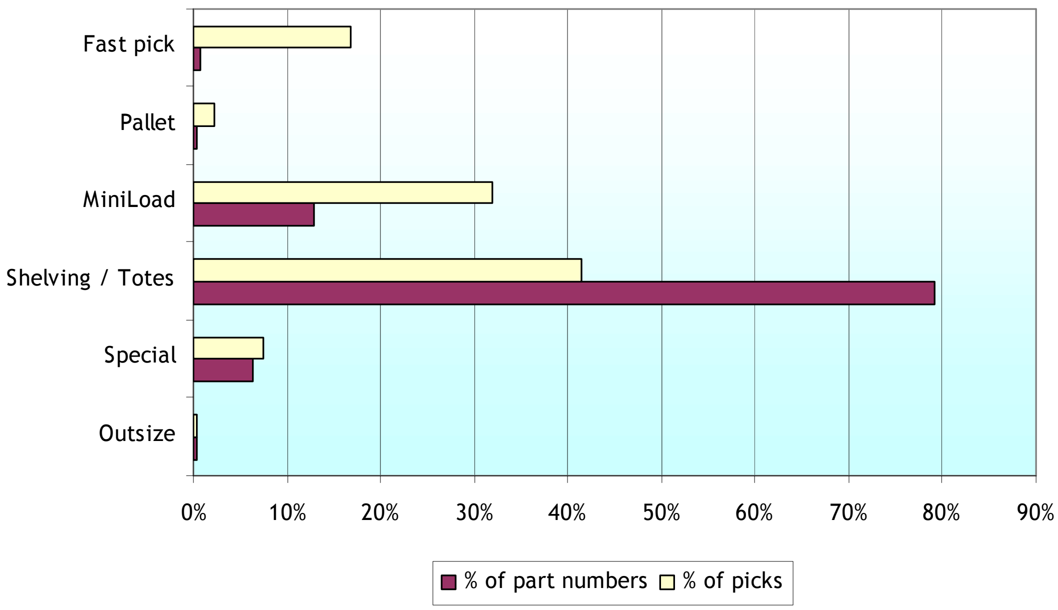

Chart – Allocation of Media for Picking

The chart shows the percentage of products allocated to each picking media, together with the percentage of picks to be carried out. In general the model has allocated faster moving products to a miniload system (to reduce labour requirements) or large shelving (to reduce the frequency of replenishment), whilst slow moving products have been assigned to smaller shelving and totes.

The results were used to design dedicated areas for the picking of fast moving products, to configure miniload picking systems and to design picking areas for slower moving products. This allowed the vast majority of picking activity to be concentrated in relatively small and ergonomically designed areas.

Conclusion

This paper has attempted to highlight the benefits that can be gained through the correct focus on internal distribution centre operations. The development of an integrated supply chain model to address this area has overcome some of the historical barriers to unlocking these benefits.

In developing the model, we have avoided the complexities of optimisation algorithms. Instead, we have integrated the inventory elements and storage design elements using an iterative approach to optimisation, relying on the speed of the model to perform the calculations required for each assessment.

This approach has delivered a number of interesting benefits to the projects we have described:

- Practical recommendations to improve efficiency and productivity within existing operations.

- A clear understanding of the issues amongst the project team allowing implementation plans to be executed effectively.

- Thorough and rigorous assessment of technology options avoids inappropriate capital expenditure.

- An operational tool that can be used by the local management team to optimise performance on a regular basis through reanalysis of the product range against latest data.

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