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Title: THE DEVELOPMENT OF A DEMAND–DRIVEN INTERNET-ENABLED PLANNING, CONTROL & DISTRIBUTION SYSTEM IN THE FOOD PROCESSING SUPPLY CHAIN SECTOR.

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Abstract:

Much research to date attempts to classify supply chains in terms of their product type (Fisher, 1997, Lamming et al, 2000), market type (Childerhouse and Towill, 2000), functionality and operations (Kehoe et al, 2001, Cox et al, 2000). The purpose of these classifications is to gain a better understanding of supply chain dynamics for the purposes of developing strategies for managing supply chains in a more efficient and effective manner.

The supply of staple foods has become both increasingly competitive, as a result of the economic downturn due to the collapse of global markets, and unpredictable, as a result of seasonal variations due to extreme weather phenomena associated with global warming. The above dynamically affect not only farming and harvesting, but also the distribution of crops and goods around the world. Such prevailing economic and meteorological conditions force companies to have multiple options for sourcing products from international suppliers in

order to reduce risk and get to market, with a potential increase in costs. Hence, the sourcing, supply, processing and distribution of products are greatly dependent on not only traditional values such as product price, its quality, geographic location, farming methods, etc. but increasingly are subject to prevailing economic conditions, which are susceptible to many variables including the price of fuel, availability of credit in world markets, etc. affecting the extended supply chain within which such products are sourced.

Introduction

Traditionally the UK has sourced much of their staple foods, such as corn and wheat from international markets including central and southern Europe, where weather conditions are conducive to their farming. However supply policies affected by global environmental concerns and increased freight and distribution costs have resulted in a greater shift towards localised food supply networks, with the UK increasingly being serviced through continental and regional European markets. The supply chain for staple foods, such as maize, sugar and wheat, is characterized by high volume high velocity production. Supply chains of this type, i.e. low product complexity, exhibit specific characteristics in that they are managed by relatively simple process-based manufacturing systems. Demand is usually forecast and production is aggregated in large batch sizes. Product demand patterns are mostly stable, although, to a much lesser degree than others, subject to seasonal variations resulting from fair weather and festivities. In spite of this, forecasting accuracy is usually low. This together with lack of alignment of manufacturing and distribution, results in inefficiencies in the form of either excessive inventory or deteriorating customer service levels and stock write-offs due to quality issues.

One method of offsetting the effects of uncertainty in supply of world food markets due to climatic variation or socio-economic factors is to decrease the overall costs of acquisition. This is achieved by creating efficient and synchronized supply chains which are demand-driven and customer-facing, allowing for increased profit margins to be established and maintained. This in turn offers a greater margin of recovery when attempting to absorb costs associated with increased acquisition, in the event of such costs being passed up the supply chain. The above may only be achieved through the development of holistic systems specifically designed for the efficient management of the extended supply chain, from supplier to the client including the all-important logistics function.

The case study presented herein addresses the development of an Internet-enabled planning and control system, which was used in the supply chain for reconciling the supply and demand activities in procurement, supply and distribution of corn grits to the snack-chip and breakfast food industries.

Objectives

The aims of this research focus on the need for alignment of the physical/information structures and processes to product demand patterns, for the purposes of managing high velocity production associated with the food industry. The objectives of this research were to develop efficient methods for management of the demand and logistics functions within manufacturing supply chains by reducing overall operating costs through reduced inventories, responsive replenishment leading fewer stock-outs, improved customer service levels and reduced delivery rejections due to oversupply.

Scope

The research addresses an international large manufacturer of globally branded breakfast cereal and snack chip product, which is based in the UK. The case study was carried out at a corn processing plant, the largest in Europe, which is located in Liverpool, U.K., and describes the development of an Internet-enabled manufacturing, planning and control system in the procurement and supply of corn grits from European agricultural consortia. The case study addresses the development of a demand-driven Internet-enabled "pull" system for reconciling supply and demand activities. The type of supply chain described herein supports the global model for the food industry, where the sourcing and procurement of food stuffs is from international suppliers based on seasonal supply and demand patterns. Such demand patterns are dynamic, being subject to prevailing political, market and socio-economic conditions and agreements, which in turn affect amongst others, the exchange rates of local currencies. This directly impacts profit margins, as deals are largely negotiated and conducted based on the US Dollar currency denomination.

Case Methodology

In reviewing the development of Internet-enabled planning and control/distribution systems for the food processing sector, the DOMAIN multi-stage methodology was used; see Michaelides et al, 2002 and Michaelides 2003. This 4-stage methodology follows the modified waterfall method and starts with the problem identification stage (or as-is analysis using value stream mapping), followed by the value proposition (or e-proposition/to-be analysis), prototyping (using RAD –rapid application development methodology) and finally the development/testing/deployment iterative stage.

The case study introduces the company, its products and the scope of its activities within the specific sector. This includes a review of its existing business model and supporting operational, functional and information system/process flows. The value proposition involves re-alignment of the existing business model to the proposed e-enabled pull-type/demand model. The development of a prototype system follows to illustrate the operational and information alignment of the proposed e-enabled business model. This prototype application is based on Internet technologies and the development of the IPL - Internet Presentation Layer (Michaelides 2003). IPL is a concept for e-enabling visibility and transparency by sharing supply and demand information as well as inventory data, in order to improve synchronization of material demand and alignment of information flows within manufacturing supply networks. An extension of the IPL to include the logistics and reverse-logistics functions has created further opportunities for enabling synchronisation, which was demonstrated during the final development/deployment iterative stage.

Although extensive simulation modelling was carried out during this case study, and its overall results are referenced herein, the actual simulation modelling part of this work is outside of the scope of this paper.

Company background

The company is the largest dry corn mill in Europe, producing high quality/ tight specification products with for the world-wide food, drink and agricultural supply markets. The company produce grits and flours from maize mainly sourced from south-eastern Europe at their plant in Liverpool, UK. Since 1999, the company is a wholly owned subsidiary of one of the world’s largest International food processing companies. At present the company supplies over 50 other companies in the UK, including snack chip manufacturers, breakfast food manufacturers and breweries.

Process description

Processing of the product involves undertaking various sieving, cleaning and milling operations in a split-mill facility. The split mill processes many different types of products, such as fine corn grits, e.g. for breakfast cereals such as corn flakes, coarse corn grits, e.g. for breweries such as stout. The Greek-supplied corn grits are unique in that they are exclusively used in the large snack-chip market, such as the popular tortilla type branded Mexican corn chips. The split-mill has the capacity to process only one type of product at each given time. Additionally, the processing operation is extremely time consuming and also involves specific setting-up of the split-mill for each type of product to be processed. Typical cleaning operations involve a throughput of 8 tonnes per hour, with an associated setting-up time of 0.5 hours for each run. Therefore, it is not possible to carry out intermittent production changes, often necessitated by late demands or last-minute schedule updates, due to the nature of both the process and the product on hand.

Processing through the split-mill prepares the corn one stage before its final production phase, after which it is dispatched to the relative companies, who will almost immediately use the material to manufacture their final products. Failure to deliver for any reason, e.g. due to quality, supply or logistics related problems, directly impacts on the client company's production schedules in an adverse way. Therefore, the planning and control of activities and the management of resources in the supply chain assumes a critical role in the company's operations, since tight schedules do not allow much room for recovery plans to be effectively executed.

Market and product description

The *market* for the products could be briefly described as follows:

- Relatively predictable, however subject to a seasonal fluctuation (celebration and good weather, although this is not proven to be a radical trend); with small changes in market demand patterns; competitive but not fiercely so; largely brand dependent; high velocity; promotion-driven and often event-driven.

The *product* on the other hand can be summarised as follows:

- Stable in terms of material and innovative in terms of flavour, promotional products and packaging; relatively low rate of new products introduction; functional product but with fast rate of innovation in presentation; trend-orientated; non-complex and high-volume with short lifecycle.

Supply chain description

The supply chain involves the procurement of corn grits, including a specific type of corn farmed in northern Greece and used to produce a particular type of corn chip for the huge snack market. This corn is subject to a limited supply, with the company purchasing the complete yearly produce from a Greek co-operative farmers union. The purchase of the yearly stock is done years in advance and is brokered through a broker in France and the co-operative farmers union. The corn is shipped in an un-processed state from a port in northern Greece to the East Anglia port of Goole, near Hull. Here the product is stored until demanded by the company for intermediate processing at its plant in Liverpool in west England. Following this, the product is transported by road for final processing at the customers plant located in Coventry in the Midlands.

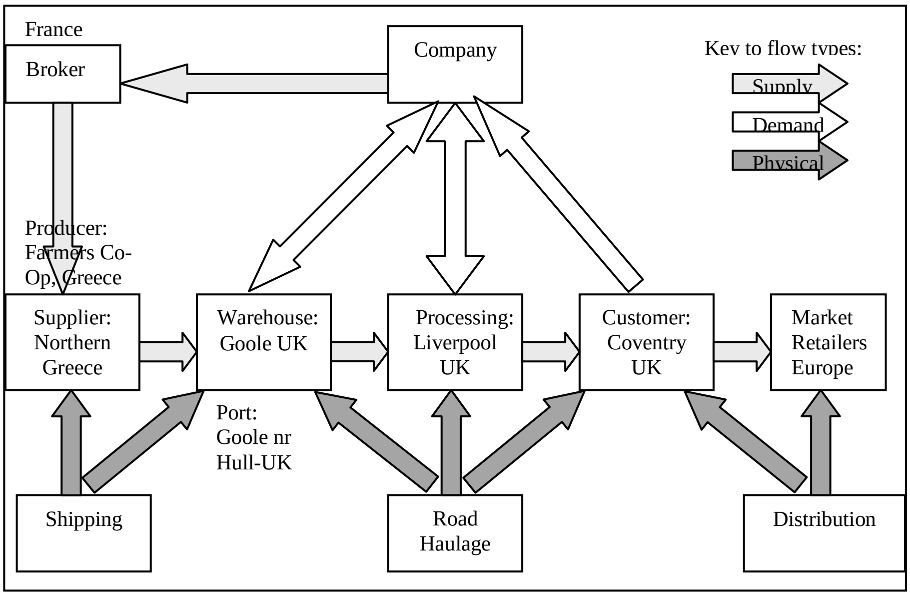

FIGURE 1: As-is supply chain, high-level information, operation and physical flows.

Physical flows

The physical flows associated with the movement of products in the supply chain are substantial and geographically diverse, see Figure 1. The products are characterized by their high volume, long distance batch movement. The supply chain processes approximately 200 tonnes of maize per week and the weekly demand is forecasted at the customer towards the end of the previous week. An equal amount of un-processed maize, to match that of the forecasted amount, i.e. approx. 200 tonnes per week, is transported by road from the warehouse in Goole to the processing plant in Liverpool. The week's demand is processed at the cleaning mill in a single batch and forwarded in a single, multi vehicle shipment to the customers' site in Coventry. Delivery is undertaken at pre- determined times, with the arrival of the shipment planned to coincide with manpower availability at the customers site for offloading purposes. Offloading is refused outside of the pre-determined window and shipments are rejected for late arrival.

The physical flow involves three types of product in the supply chain. The first type is un-processed maize, from the producer in South-Eastern Europe. The second type is processed maize from the supplier in Liverpool, west England. The third type is the final branded product, namely corn chips, from the manufacturer in Coventry in the Midlands, and is outside the scope of this paper.

Information flows

The company uses a make-to-order type of planning and control system in its operations. Make-to-order planning and control system are used in operations where sufficient confidence exists in the nature of demand, if not in volume and timing (Slack, et al, 2001). Both the large product lead-time and product specification have led to the adaptation of this specific type of planning and control method. On the one hand, large lead times do not allow the company to adapt a resource-to-order approach and on the other hand the perishable nature of the product once it has been processed, is not conducive in using a make-to-stock approach. Hence, the ratio of throughput time over demand time (P:D) defines the velocity of production in this particular supply chain, (Slack, et al, 2001). Therefore, in describing the make-to-order method adapted by the company, we see that large quantities of maize are purchased from producers in Greece, from where they are shipped and keep at the company's warehouse in Goole, near Hull in East England, until required. The maize is processed-to-order by moving stocks from Goole to the plant in Liverpool, in response to customer forecasted demand. Following the processing operation, corn grits are delivered to the customer by a sub-contracted haulage company.

In considering the information flows, the demand requirements are transmitted in weekly batches and are sequentially communicated along the supply chain, i.e. the customer advises the supplier, who in turn advises the processing plant, from there to the warehouse and on to haulage contractor. Depending on the levels of stock on-hand, the demand channel expands accordingly up the supply chain, to include the next level of material supply. For example, if the processing plant at Liverpool cannot meet the demand with locally held stock, it passes on the demand, or parts thereof, up the supply chain to the warehouse in Goole for stock replenishment. Similarly, should the warehouse in Goole require additional stocks, this demand is passed on to the broker, and so on.

As stated previously, ordinary level communications do not allow for any system intervention, such as verification from an MRP system. Therefore, exchange of key information is allowed to take place outside the bounds of a planning and control system. Under these conditions the data exchanged or communicated in the supply chain is by no means considered definitive, since it remains dynamic and subject to change without notice. Subsequently, the data and information on hand may not be considered as representative of the true state of supply and demand within this specific supply chain. For example, inventory figures, which may have been the source of the original demand, may have changed in the interim as a result of customer promotions. These variations in actual demand may not have been taken into account by the supplier since they have not been made aware of such activity. This subsequently leads to fluctuations in supply and demand, resulting in overstocking as a means of smoothing the effects of such variations.

Problem Description

Product demand is usually forecast and production is aggregated in large batch sizes. Product demand patterns are mostly stable, although subject to seasonal variations resulting from fair weather and festivities. In spite of this, forecasting accuracy is usually low. Stock replenishment is carried out using an order-point system at the supplier-end due to the relatively stable demand patterns. At the company when the quantity of processed maize in the silos falls below a specified level, a replenishment demand is internally generated to meet the stable weekly forecasted amount of 175–200 tonnes.

The customer uses a materials requirements planning (MRP) system to forecast demand at its facility. The type of demand generated at the customer is dependent-type demand, i.e. it is dependent on the demand for a higher-level end product (Scott, 1994). Therefore, the amount of stock held by the customer on-site in their silos appears in the first instance to be more representative of the company's actual production requirements. Despite using an MRP system to meet its dependent demand, the customer often reverts to using an order-point system in replenishing its stock levels. This is done because short-term demand changes are not effectively accommodated in this type of supply chain due to constraints imposed on by the process and logistical arrangements. For example, process constraints are imposed on as a result of long set-up times and long product processing times at the supplier's split-mill facility. Logistical constraints are imposed as a result of short-term availability of transport, long distance delivery runs and offloading restrictions as a result of manpower availability at the customer site. Thus, by maintaining high stock levels in its silos, the company overcomes short-term independent demand variations. Final items or finished goods are an example of independent demand. Scott (1994), states that it is not sensible to forecast demand for dependent-type items, such as corn grits, as if they were independent-type items, such as snack-chips, which is the case when overriding the MRP system in favour of the order-point system by the customer. The role of demand forecasting and the differentiation between dependent demand and independent demand is central to the MRP concept, (Scott, 1994). Scott, 1994 further suggests that such demand should be generated from known or forecast demand of the parent components, of which they are integral component parts. This does not take place.

The problem of information flow manifests itself when further considering the role of the logistics provider. The haulage company is not afforded any visibility of current inventory neither upstream at the supplier's warehouse or processing plant, nor downstream at the customer site. In planning to deliver the contracted load to the customer, the haulage company is unable to verify whether the necessary capacity exists in the silos to accept his expected delivery quantity prior to setting-off, which often results in refusal of delivery. Each failed delivery at the customer has an additional impact on the overall operation, since this in turn adversely affects the supply route from the warehouse to the processing plant. The haulage company is thus unable to complete their round trip and must return to the processing plant to off-load the rejected stocks. This practice therefore not only reduces customer service levels, it also affects stock replenishment operations. Furthermore, it negatively affects relationships between the supply chain members, where the costs associated with failed deliveries are expected to be absorbed.

Table 1 below summarises the main problems associated with the food processing case study. It is of note that many of the current issues identified herein are typical of other case studies in other sectors, indicating a large degree of commonality exists.

	Problems/CAUSES:	Affecting:	Resulting in/EFFECTS:
1.)	Cannot view 'downstream' customers inventory levels, for replenishment purposes	Customer	• Stock-outs • overstocking
2.)	Cannot confirm capacity exists for customer stock replenishment	Haulier/ Company/ Customer	• declined deliveries • delivery rejections on perceived quality issues • poor customer servicing levels • increased delivery costs • revised delivery schedules
3.)	Stock ordering based on independent not dependent demand	Customer	• increased inventory holding costs • overstocking • stock-outs
4.)	Inventory managed by the customer and not the vendor	Company/ Customer	• no visibility • no synchronization of supply and demand patterns • no 'pull' type demand elements

Table 1: Problems areas associated with the food processing case study.

Value proposition

The next stage of study involves proposing systems to address the problems previously described. In order to address this requirement, it is necessary to address supply coordination and synchronisation of information flows in an aligned manner. Such systems should be based on Internet technologies, supporting open standards of communication and information exchange. Furthermore, such systems should promote visibility and interactivity of the manufacturing task in the extended supply chain. A method of enabling the proposed interaction is based on the concept of the Internet presentation layer (IPL). This technology allows real-time manufacturing data, such as manufacturing schedules, production plans and inventory information to be dynamically shared and acted upon by all members in the demand chain.

Prototype Application Development

The purpose of the prototype application development for this case study was to use Internet-enabled technologies to extend the functionality of existing legacy systems. The requirement was based on the use of shared data sources and the development of an Internet presentation layer (IPL) to provide visibility in the supply chain, see Figure 2. The aim of the IPL was therefore to promote pro-activity in the supply chain and enable data interchange between users via a standard Web browser, such as Internet Explorer. Development of the prototype application and hosting was carried out at the University of Liverpool. The prototype system was based on three-tier client/server architecture, open source systems were largely used, the database layer was MySQL but Microsoft SQL server was also used for prototyping purposes.

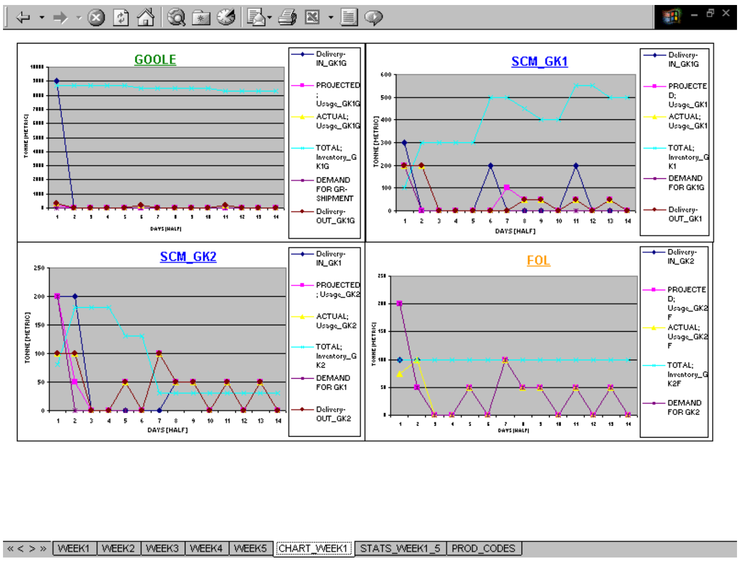

FIGURE 2: Internet Presentation Layer, graphical representation

Collaborative e-business solution

The physical and operational alignment proposed was to adopt a lean, pull-based approach whereby the single piece to flow through the supply chain was the haulage quantity of around 25 tonnes, being the equivalent of a single (truck) measure of a typical batch supply. In addressing the information alignment to support this operational strategy, both the independent as well as the dependent demand forecast data were synchronized throughout the demand network. This resulted in affording each member the required visibility in terms of actual demand and true inventory status throughout the entire supply chain. Additionally, the introduction of the haulage company to this pull-based operation was key in enabling the actual movement of materials to coincide with the required supply and demand patterns, thus offering both a holistic as well as a synchronised and coordinated logistics solution.

The concept was demonstrated by developing a supplier portal site, using a web interface containing synchronised supply and demand information necessary to achieve operational alignment. The implemented e-solution, which is based on making the demand data continuously available for the supply chain parties to pull and synchronise their operations with the demand, has been found to comply with and support the supply chain strategies suggested by the physical/information system model. The solution's characteristics of being a single portal, providing supply and demand visibility, and focusing on transactions and costs associated with them correspond to the devised strategies of vertically integration, synchronisation, and efficiency of the supply chain.

Simulation results undertaken for this case study have shown significant reductions in acquisition and operational costs, which justify the use of e-enabled supply chain solutions in food processing industry (Ho, 2002). In modelling the business impact of this e-solution two important benefits emerged. Firstly and not surprisingly the overall inventory level within the supply chain could be reduced and the utilisation of transport vehicles improved both of which reduced the cost of operations for the entire chain. Secondly the dynamic response of the supply chain to a step change in demand (the traditional bullwhip or Forrester effect) was significantly improved and the need for the wasteful "quality problem" correction mechanism eliminated. This can also provide some grounds for a better relationship pattern along the supply chain, one based on clarity of value, better appropriation of value, and trust between chain members.

Comparison between models

In reviewing the existing model it was confirmed that the sequential nature of operations leads to a lack of effective communication. This results in 'islands of information' developing at each point in the supply chain. The nature of such information is critical since it is subsequently transformed into data and input into systems to further plan, control and overall manage the supply chain. An example of such information is forecast demand, which is subsequently input into an MRP system and used to drive the materials requirement planning function of a company. Although material movements do take place, the reasons for such movements are not always clear or correct to all members in the supply chain. The subsequent asynchronous movement of information and material flows leads to fluctuations resulting in step changes in demand and overstocking. See Figure 3

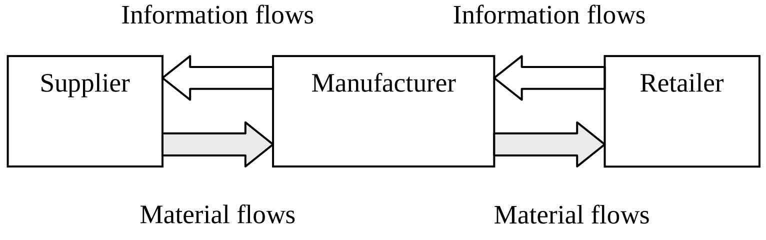

FIGURE 3: Traditional sequential operational, physical and information alignment

In order to overcome these problems, a synchronised approach is required, offering visibility in the supply chain while promoting supplier interaction and collaboration within the wider network. This is achieved through adapting a demand-based, collaborative e-business solution for information and operational alignment. The proposed system is based on the Internet presentation layer (IPL), a concept for dynamically viewing supply and demand information as well as inventory and capacity data over a shared network, see Figure 4. This model supports synchronised physical and information flows and eliminates fluctuations in supply and demand patterns by making current data available to all supply chain members. This results in a lean pull-based approach, using enhanced visibility where capacity and inventory information is shared, thus avoiding overstocking situations by enabling efficient deliveries, which are not subject to rejection on the grounds of perceived inconsistencies in quality. Furthermore, the collaborative model is conducive to establishing better inter-supply chain relationships by promoting open communications and fostering partner-based interactions. The inclusion of the logistics function further promotes synchronisation of support activities and collaboration.

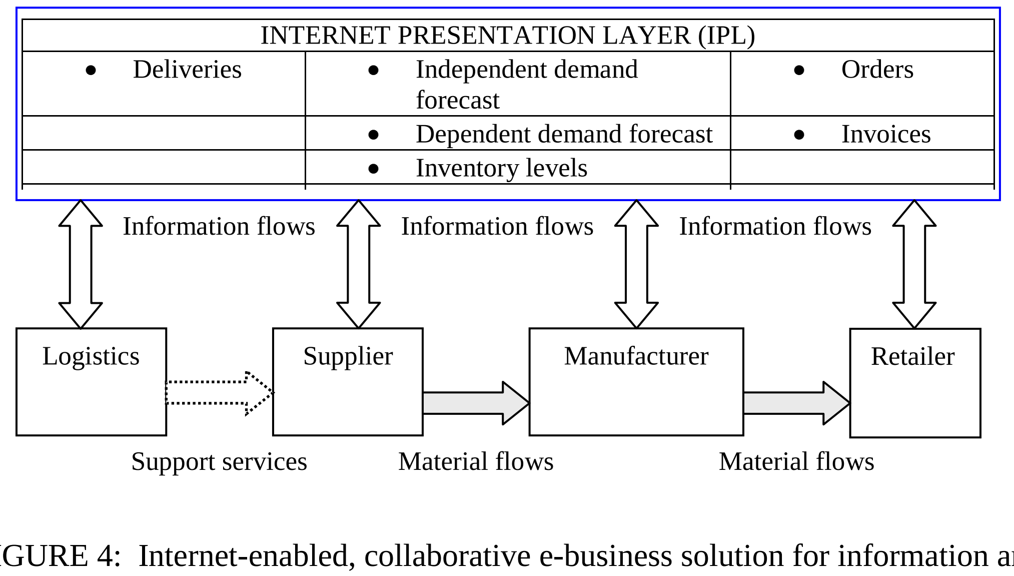

FIGURE 4: Internet-enabled, collaborative e-business solution for information and operational alignment.

Conclusions and further work

The manufacturing supply chain in the food industry displays unique characteristics and is subject to much uncertainty related to socio-economic as well as climatic conditions. Low product diversity coupled with high volumes translates to a need for highly tuned supply chains. In order to offset the effects of uncertainty in the supply chain, the development of suitable planning and control systems is key in maintaining efficient operations, where profit margins are increased resulting in costs being able to be absorbed in the event of them being passed up the supply chain.

The DOMAIN 4-stage methodology was adapted in achieving the requirements of this case study. Specifically, the company's current business model was re-evaluated and alignment of the physical/information system flows and process to a revised operational e-business model was enabled. This was followed by the prototype development stage, where e-enabled applications were introduced and operational improvements were applied to specific areas, such as scheduling. These systems were developed and implemented by applying Internet technologies as solutions for enabling visibility and sharing of supply and demand data in the supply chain, while considering the company's unique market and product characteristics. Finally, the value stream analysis stage addressed the advantages gained in achieving this information alignment to support this operational strategy and compared the 'as is' operation to the e-enabled solution. In reviewing the overall supply chain operation, the advantages of using Internet-enabled planning and control systems were demonstrated by reduced inventory levels, achieving fewer stock-outs and improving customer service levels by reduced delivery rejections due to oversupply.

The requirement to develop an additional layer of data presentation was met by the development of the IPL, which provided visibility in the supply chain resulting in efficiency gains through better planning and scheduling of the processing activities. Furthermore, this resulted in synchronised operations in production, transportation and inventory, supporting the development of a ‘pull’ type business model in the supply chain. Incremental gains in efficiency were also achieved by linking the logistics function to the overall operation thus enabling supply and demand as well as inventory data to be shared and worked on in an aligned manner in the supply chain. Thus, it was found that the proposed e-business models and solutions positively impact the communication patterns along the supply chain, influencing the power and trust relationships established between the partners, resulting in a more robust alignment of the supply chain.

In terms of future work, this research proposes a way forward for supporting alignment in the areas of SCM, MPC and ICT through the concept of the Internet Presentation Layer – IPL. Future work involving the development of suitable integrative frameworks for identifying and grouping the alignment characteristics and structural elements of each of the areas listed above is currently in progress. Such frameworks shall demonstrate the structural alignment of these areas with the underlying physical and operational configurations, information and knowledge flows and behaviour and relationships arrangements. As a result, application of this integrated framework shall further enable the synchronisation and coordination of data and information, thus supporting efficient operations in the food-processing sector.

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