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Solutions to improve performance in the UK house building supply chain - The use of a system dynamics model

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Abstract

The private house building industry in the UK is plague with problems. Two major governmental reports have shown the need to change and to improve performance if the house developers are to survive. In order to assess the potential benefits of using supply chain management principles for the house building industry, especially from a dynamic point of view, a generic model has been developed and used. This model based Forrester production and distribution systems and on an Inventory and Order Based Production Control System (IOBPCS) takes into consideration the developer, merchants and manufacturers.

This generic model has been used to model four scenarios for the low-value fit-out supply chain. The low-value fit-out supply chain focuses on products necessary for the construction of the fit-out of a house such as doors, lintels, skirting boards, etc. The four scenarios considered are Traditional, Kitter, Integrated Information and Synchronised. Each scenario implement different supply chain management principles such as supplier base reduction, total cycle time compression, shared end-customer demand, etc.

The simulation results show that using one single national merchant instead of several regional merchants reduces demand amplification and total supply chain inventory costs. Information enrichment also improves performance while the reduction of manufacturing lead-times has detrimental effect on the total supply chain inventory costs.

It is concluded that the private house building can improve its performance by implementing some supply chain management principles.

Key words: Supply Chain Management, house building industry, system dynamics simulations

Introduction

The private house building industry in the UK is well-known for its problems. First of all, Sir Michael Latham highlighted in a report in 1994 entitled "Constructing the Team" the problems that plagues the construction industry in the UK and offered some guidelines to improve the performance of that industry (Latham, 1994). Few years later, the Egan report was published where good results of parts of the industry, for some specific construction projects, were acknowledge but also reiterated the need for overall performance improvements (Egan, 1998). This report especially encouraged the construction industry to learn from other industries to improve performance.

The private house building industry still suffers from many problems, some inherited from the construction industry in general such as cultural problems, others inherent to the speculative house building industry. A brief summary of some of the principal issues may provide a clearer picture of the current state of the house building industry within the UK.

First of all, the UK house building industry can be criticised for not focusing on their customers by not delivering the right product or the right quality or in the right location. Further, the house building industry has been accused for being excessively standardised offering relatively low quality for expensive costs (Ball, 1996). This comes from the fact that generally, house builders use a house portfolio. 75% of the house developers building more than 500 units a year utilise a portfolio composed of 20 or more standard house types to cover the market (Nicol and Hooper, 1999). A general lack of customisation of the houses offered by the developers has been acknowledge (Barlow, 2000). This goes against the findings of a survey of 1,000 people carried out in 1998 by "2000 Homes" (now the Housing Forum). This opinion survey revealed that more than 83% of the participants would like flexibility, offering choice over the initial design of their homes. This lack of customer focus can be explained by the fact that UK house builders are more focused on production and sales targets than on the final product, the house.

As a matter of fact, house builders have always reached higher profits through land acquisition and speculation than through the construction of the houses themselves. However, this is changing. First of all, the developer's land banks have reduced in size during the last decades and finding suitable land for housing development is becoming an increasingly difficult task (Ball, 1996; Barlow, 2000). Furthermore, the government is pressurising house builders to build on brownfield sites, which has severe consequences on construction costs.

Another major problem for house developers occurs during the construction stage, where supplier performance is poor. Getting the right material to site at the right time for the right cost is not an easy task.

The house building industry and the construction industry in general is well-known for its adversarial type of relationships characterized by a lack of trust and commitment between parties (Bresnen, 1996; Holti, 1996; Larson, 1997; Barlow, 1998). Related to these adversarial relationships, communication between companies is also very often not effective. In many cases, information is not always readily available (Latham,

1994) and is often incomplete or inconsistent (Construction Productivity Network, 1997). The success or failure of a construction project's execution depends on the understanding of the information needs and requirements of the different parties (Love et al., 1999). Inadequate, incomplete and outdated information can lead to delays and extra costs during the design stage but also during the execution of a construction project.

In addition, as for all industries, the house building industry suffers from demand amplification along its supply chain. Evidence of this phenomenon in the housing industry was reported by Lewis (1997) and is presented in Table 1. Lewis' (1997) example of demand amplification comes from the study of a ventilation systems manufacturer. Table 1 reveals that as demand is passed along the supply chain from customers to suppliers, it is distorted and amplified.

Average weekly demand from customers	**Variability in weekly demand from customers**	**Average demand placed on suppliers and frequency**	**Variability in demands placed upon suppliers**
48 per week	Up to 150%	400 every 6 weeks or 200 every 3 weeks	From 100% up to 300% depending upon frequency

Table 1 Amplification and variability in demand as it is passed along a ventilation manufacturer supply chain (Lewis, 1997)

The present house building poor performance was until now not encouraged to improve as the house developers make more profits on the land resale price more than on the houses they build. However, this is changing. First of all, although international competition is still minimum due to a lack of appropriate suppliers and labour (Barlow, 1999), the competition is starting and will increase in the next decades. Furthermore, the environmental legislation require higher and tighter standards. Although, these standards are currently easily met by developers, they will have to investigate new ways of construction to meet the next tighter regulations (Barlow, 1999). As already highlighted above, more and more brownfield site are now available for housing development, which increase the construction costs. Finally, the shortage of skilled labour is continuously increasing the construction costs (Barlow, 1999).

Therefore, ideas for improvement and change are required. As Gann (1998) states, *"current levels of inefficiency and wasted materials, labour and time, as well as pollution, could be substantially lowered by streamlining supply chains and by introducing better management practices"*.

Model description

In order to assess the potential of implementing supply chain management principles in the UK private house building industry supply chain to improve performance, a generic system dynamics model has been developed. The full documentation of the model can be found in Hong-Minh (2001). The overall model structure is presented in Figure 1.

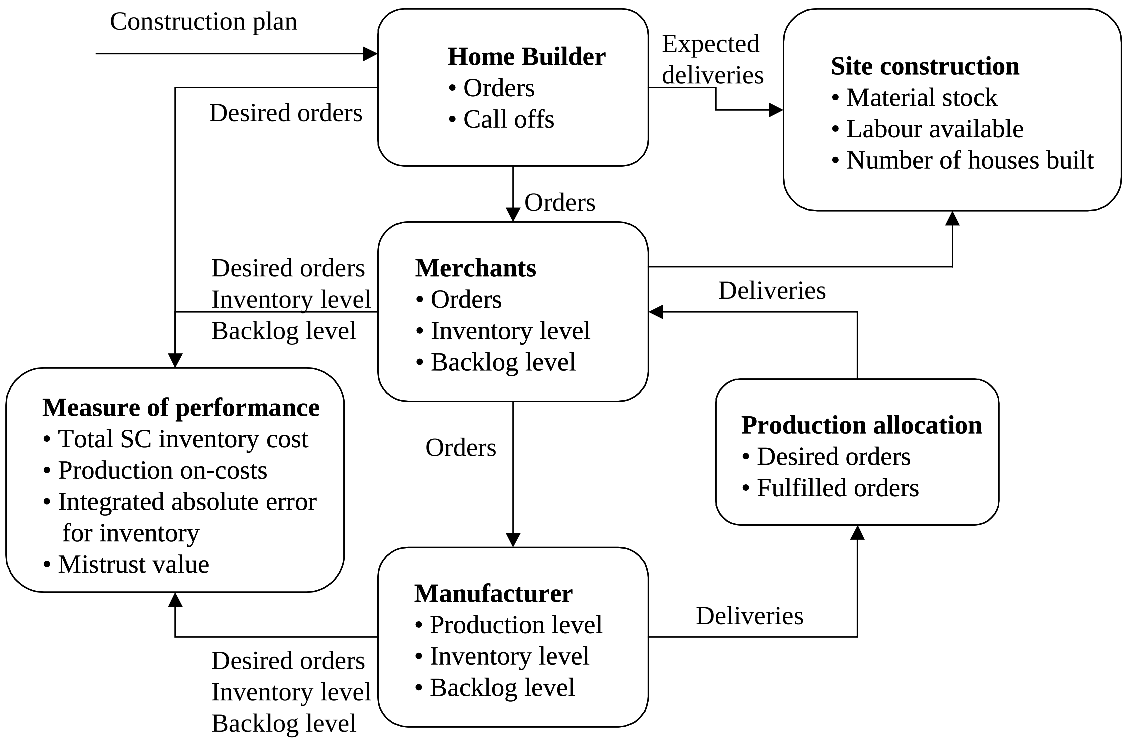


Figure 1 Model structure overview

Home Builder

Home Builder sub-system represents the house developer where the construction plan is produced. As can be seen from Figure 2, the orders placed by the regions are generated from the construction plan. The house building industry like the construction industry is based on an "order and call off" mechanism. This means that orders are first placed to suppliers and the products are then called off at a later stage whenever they are needed. A coefficient (coefficient product) has been used in order to transform orders for houses into orders for products. "Call off for the products" (C_p) is therefore equal to the orders (O) for houses delayed by λ_o multiplied by the product coefficient (p) (number of products needed to build one house).

$$C_{p(t)} = O_{(t-\lambda_o)} * p \qquad (1)$$

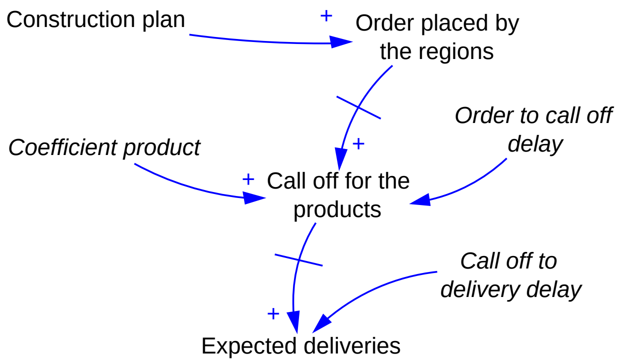


Figure 2 Causal structure for Home Builder

Merchants

Most products are currently procured from merchants on a regional basis. Therefore, as can be seen from Figure 3, the "order placed by the regions" are the demand received by the merchant. The "call off for the product" is used for the delivery of the products, i.e. to decide how many products need to be taken from stock.

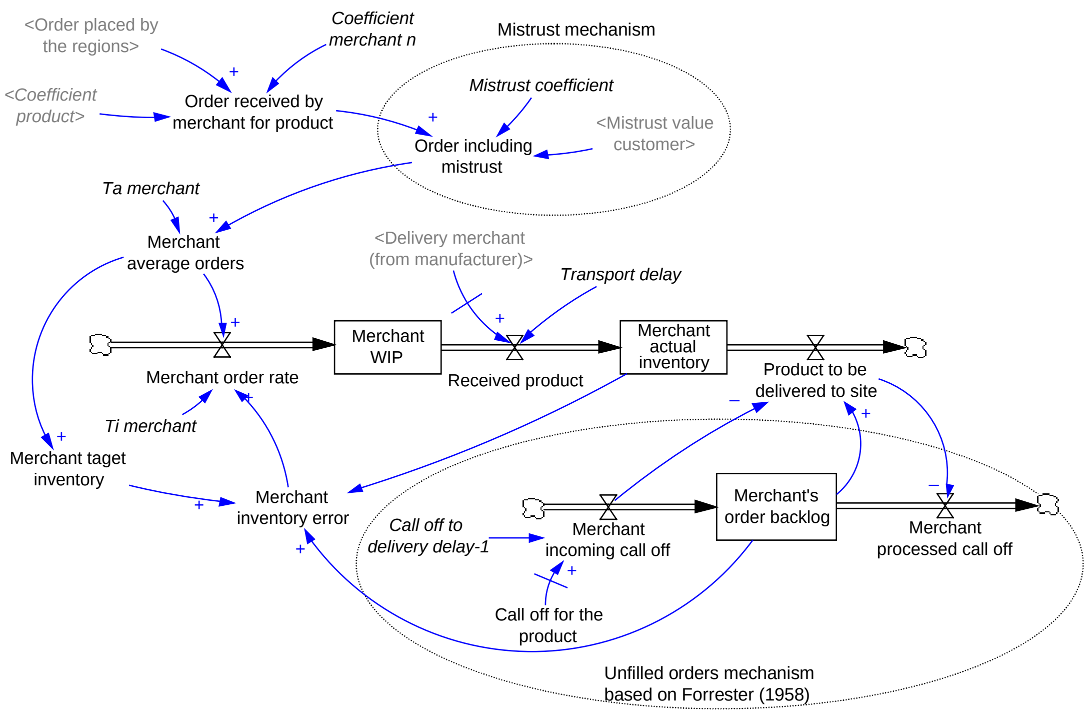


Figure 3 Simplified stock and flow diagram for Merchants

The ordering rule used for the merchant is based on Forrester's production and distribution system (Forrester, 1958) and an Inventory and Order Based Production

Control System (IOBPCS) model (Towill, 1982). This means that the level of production required (merchant order rate) is based upon the level of demand which has been averaged over a period of time T_a (merchant) and the level of current inventory in comparison with a target inventory. "T_i merchant" represents the time to adjust the inventory. An unfilled orders mechanism based on Forrester's model was added to the IOBPCS model. Therefore, if there are no products available in stock, then the products cannot be delivered.

A mistrust mechanism was also incorporated in the model in order to represent the typical adversarial relationships of the house building industry. Here mistrust is understood as being the lack of trust between trading partners. Very often this lack of trust is especially tangible when customers do not receive the full quantity of what they have ordered. Instead of trusting the supplier that he will deliver the missing products as soon as they become available, customers over-order to make sure that they will receive the real quantities they need. This principle has therefore been reflected in the model as follows: whenever the customers do not receive the full delivery of what they have ordered (O), the next order (O_m) they will place will be increased by a percentage (mistrust coefficient κ_m) of the quantity of product undelivered (mistrust value M). κ_m equals 1 when mistrust is set at 100% and 0 in the case of no mistrust. The calculation of the "mistrust value" is explained later in this chapter.

$$O_m = O * \left(1 + \left(\kappa_m M\right)\right) \quad (2)$$

Manufacturer

The merchants will replenish their stock by ordering products to manufacturers. Therefore, the "merchant order rate" becomes the "order received by manufacturer for product" as can be seen from Figure 4. Here again, the production and distribution system is based on an IOBPCS. An information enrichment mechanism, as developed by Mason-Jones (1998), has been added to the model in order to test the impact of better information transfer in the supply chain. The lack of communication and information availability has been recognised as one problem faced by the house building industry.

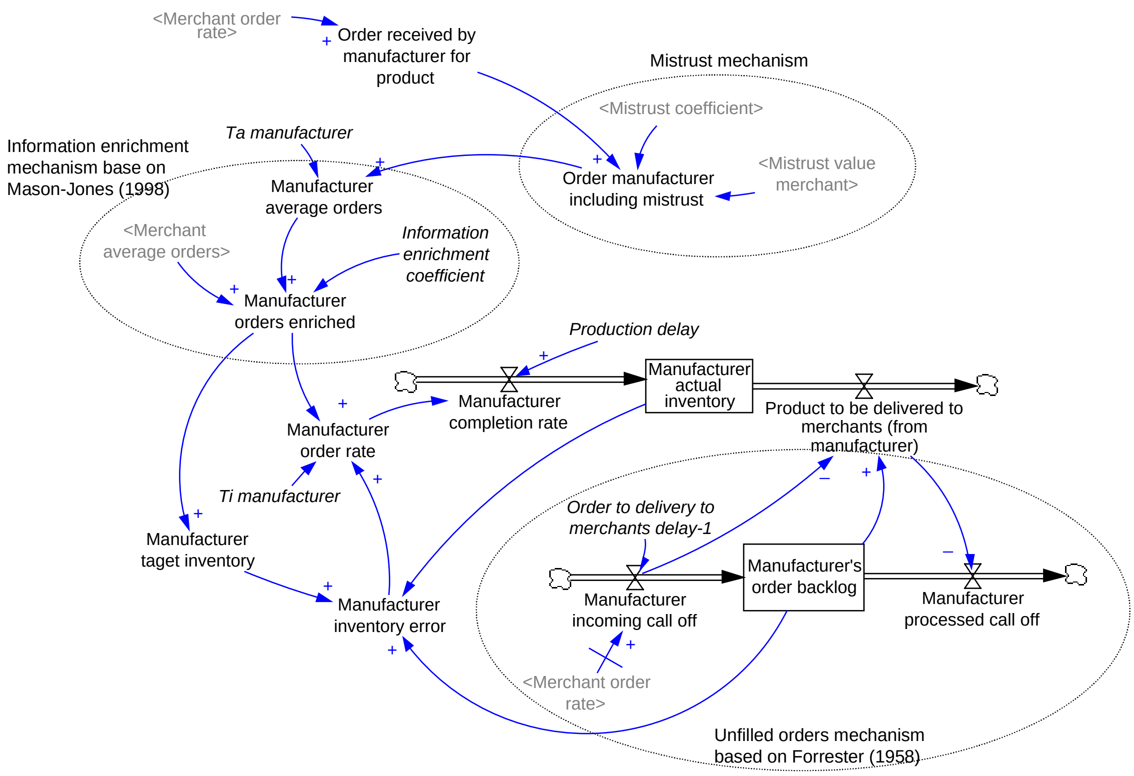


Figure 4 Simplified stock and flow diagram for Manufacturer

Production allocation

The "product to be delivered to merchants" (see Figure 4) need first to go through a production allocation process as there are more than one merchants and the total number of products available are lesser than the total merchant order rate. The allocation is prioritised depending on the amount of products ordered. The merchants ordering the most are served first, then if there are some products left, the second merchant is served and so on until there is no more product available.

Site construction

A site construction sub-system has been developed (see Hong-Minh, 2001) including labour and products. However, in the example that will be studied later in this paper, this sub-system was not utilised. Therefore, this sub-system will not be described in detail here.

Measure of performance

The model will assess several performance criteria. A review of key authors on supply chain dynamics simulation showed that the main performance criteria studied are the level of inventory (Hong-Minh et al., 2000; Strohhecker, 2000), the level of bullwhip (Chen et al., 2000; Fransoo and Wouters, 2000; Disney, 2001), the peak value, peak time and order recovery for the order rate (Towill, 1969; Mason-Jones, 1998), production on-costs (Wikner et al., 1991; Berry, 1994; Berry and Naim, 1996; Towill and McCullen, 1999), and the integral absolute error for the inventory level (Hong-Minh, 1998).

Therefore, a starting point is to consider the criteria originating from control theory, these being especially applicable to a step change in the demand (Towill, 1969; Nise, 1995). The performance is measured using six criteria: peak value, peak time, order recovery, stock depletion, trough time and stock recovery (Mason-Jones, 1998). The first three criteria are calculated for the "order rate" while the last three are based on the actual inventory level.

- **Peak value** assesses the overshoot value of the order rate.
- **Peak time** is the time at which the peak occurs.
- **Order recovery** or settling time is the time needed for the system to reach a stable state.
- **Stock depletion** is the trough value for the actual inventory level.
- **Trough time** is the time at which the stock depletion occurs.
- **Stock recovery** or settling time is the time needed for the system to reach a stable state.

However, these six criteria can be summarised using only two criteria: production on-costs and Integrated Absolute Error (IAE). The production on-costs originates from the Boston Consultancy Group where, based on Forrester work, it was estimated that the increase in business overheads due to demand amplification is *"… the cubic function of the area between the oscillating (amplified) output curve for the factory and the neutral axis"* (Stalk and Hout, 1990) as illustrated in Figure 5.

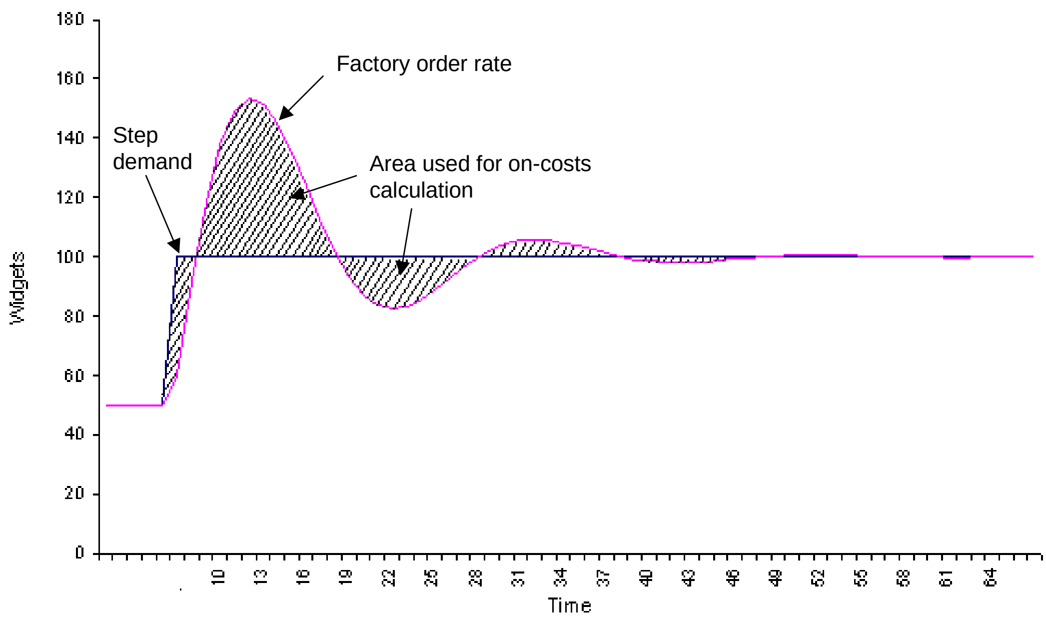


Figure 5 The Boston Consultancy Group metric for estimation of on-costs associated with demand amplification (Wikner et al. (1991) based on Stalk and Hout (1990)

The IAE is calculated for the actual inventory level and is based on the same principle as for the production on-costs. The area considered is the difference between the actual inventory level and the target inventory. These two criteria were calculated directly in the model as can be seen from Figure 6.

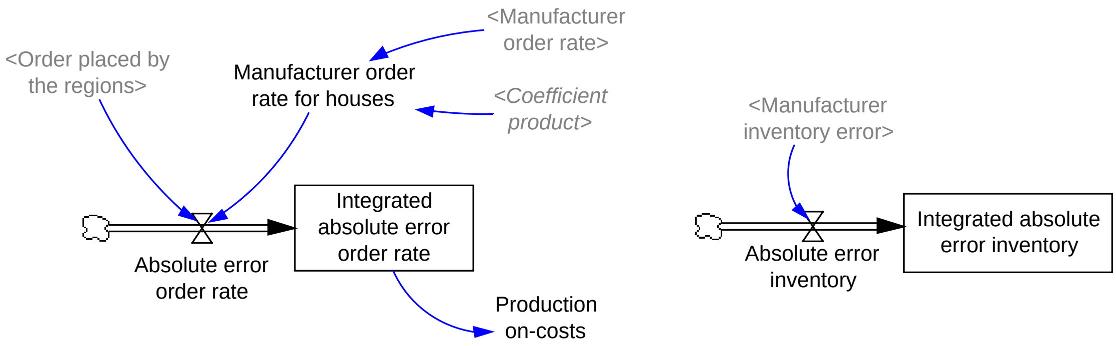


Figure 6 Simplified stock and flow diagram for production on-costs and integrated absolute error for inventory

The total supply chain inventory costs, presented in Figure 7, can also be calculated by encompassing the inventory costs for the merchants and for the manufacturer. The calculation of the inventory costs is based on the assumption that the cost for holding stock is different from the cost of being out of stock.

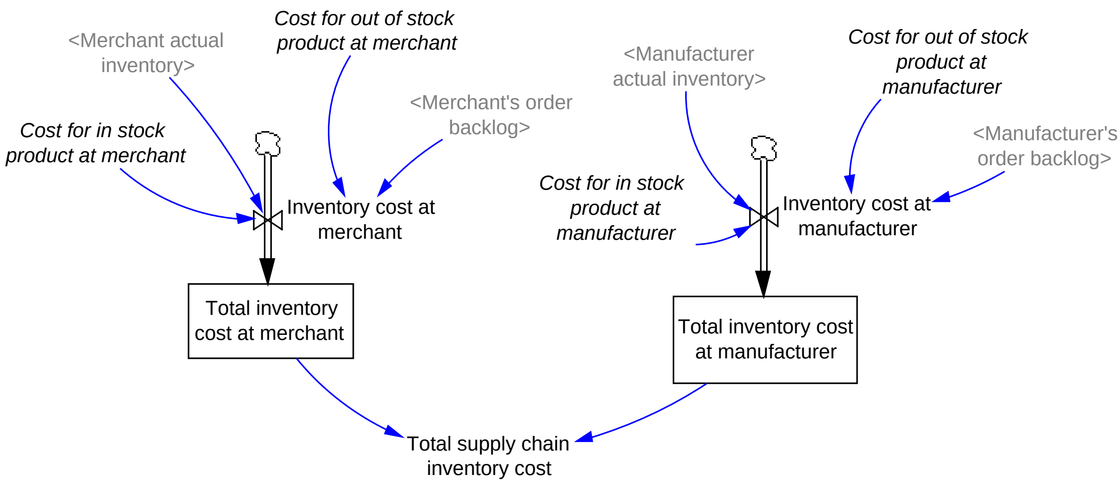


Figure 7 Simplified stock and flow diagram for total supply chain inventory cost

Analysis and results

Three different supply chains can be identified for the house building industry. Taking an open building approach, a house can be decomposed into core elements: the foundations, the shell and roof and the fit-out and services (Gann et al., 1999; Naim and Barlow, 2000). The research presented here only focused on the construction of houses once the foundations have been laid. Therefore, the main remaining components to build a house are the shell and the roof and the fit-out and services. The fit-out can further be split into two categories, the low-value fit-out (including material such as doors, skirting boards, lintels, doorframes, and nuts and bolts) and the high-value fit-out (including kitchen units, bathroom fit-out and electrical systems such as heating and ventilation systems). The focus of this paper will be placed on the low-value fit-out supply chain.

Seven “hot spots”, summarised in Table 2, have been identified during the research work carried out by the author and have been reported in (Naim and Barlow, 2000). As can be seen from Table 2, the “hot spots” cover a range of issues from lack of customer information to wastage and lack of supply chain integration. These “hot spots” can be identified by their symptoms such as poor supplier delivery performance, poor availability of material on-site or unsatisfied customers. However what needs to be tackled are the root causes, for example the adversarial approach to trading, or regional buying arrangements and purchased price based on price, or even the lack of strategy for utilising the information available.

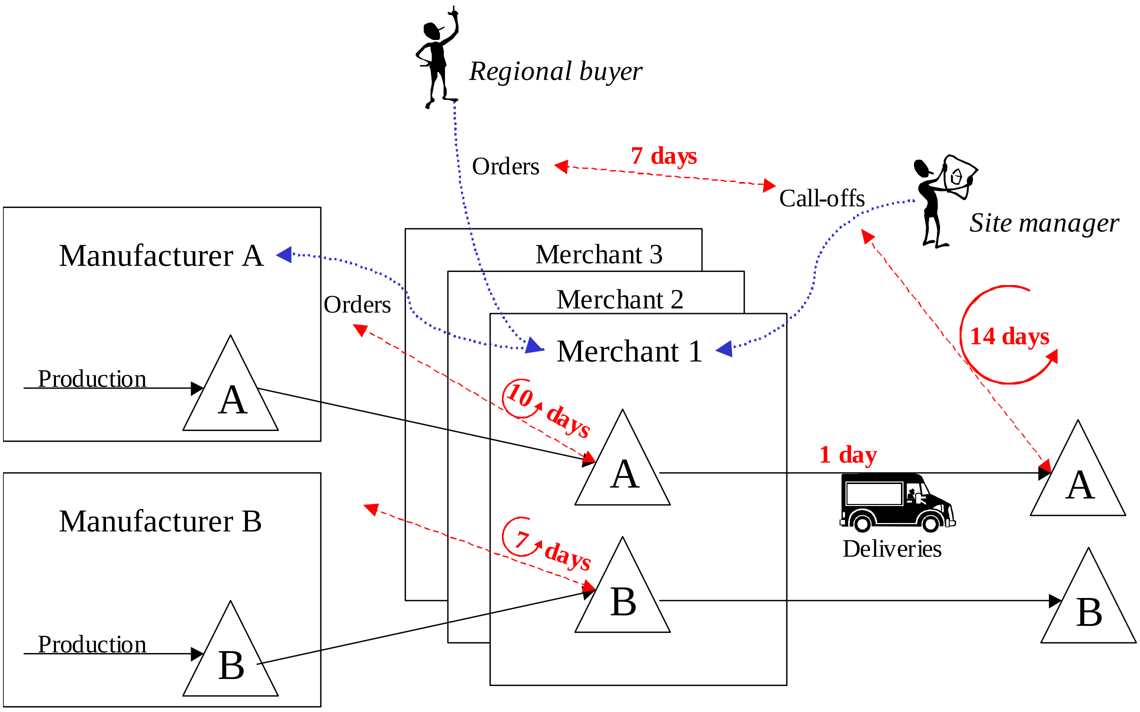
	Root Causes	Symptoms
Hot spot 1 : No use of market knowledge	• Regionally based buying agreements • Purchase based on price • No time scale guarantee for actual buying and calling off the material	Suppliers have little visibility of long-term market requirements
Hot spot 2: Lack of supply chain integration	• The site manager has co-ordinated a large amount of people and tasks • He holds a considerable amount of information • No clear strategy of how best to utilise the information	Very poor information transfer and use across the supply chain
Hot spot 3: No time compression strategy	• Lack of supplier development and adversarial relationships • Volatile short-term call off information from the site • Late changes in site requirements	Poor supplier delivery performance
Hot spot 4: Inability to rapidly re-configure	• No medium term planning horizon given to sub-contractors • High work uncertainty pushes sub-contractors to commit themselves to several tasks	Poor availability of contractors on-site
Hot spot 5 and 6: Excessive muda, or waste	• High level of stock on-site to buffer against uncertainties • No designated stocking area and proper recording mechanism lead to damage, mislaying or theft of material	Poor availability of material on-site
Hot spot 7: Muda	• Above problems lead to the need for a finishing foreman to chase material, chase labour and assign re-work and snag list	Dissatisfied customer (poor total value)

Table 2 Summary of Hot spots in the traditional supply chain of low-value fit-out material (Adapted from Naim and Barlow, 2000)

Scenarios' description

Four different scenarios have taken into consideration: Baseline, Kitter, Integrated Information and Synchronised.

Baseline scenario represents the traditional low-value fit-out supply chain as presented in Figure 8. Only two manufacturers (A and B) have been here considered, a door manufacturer and a skirting boards manufacturer respectively. The lead times presented were collected during an in-depth case study (see Hong-Minh, 2001). The orders are placed by the regional buyer and the site manager has then to wait a minimum of 7 days after the order is being placed, before he can call off the material from merchants. It usually takes 14 days for the merchant to fulfil that order, one day being taken up by the transport of material on-site. Several different merchants are used by different regional buyers, however, even within the same regions, a multiple number of merchants are used to procure different products, generally 2 to 3 per site. Therefore, 8 merchants have simulated, each merchants carrying both products.



Where A represents doors and B skirting boards

Figure 8 Traditional low-value fit-out supply chain

The replenishment of doors requires a 10-day lead-time while the replenishment of skirting board requires a 7-day lead-time. Furthermore, as identified in the hot spot, the relationships between the companies are adversarial. Thus mistrust has been modelled. Mistrust was set at 100%, which means that whenever the customers do not receive what they have ordered, they will increase the next order they place by 100% of the quantity of the products undelivered.

Kitter scenario addresses the "Hot spots" 3, 5 and 6 – poor supplier delivery performance and poor availability of material on-site – by using only one merchant, which will be called Kitter. Using only one merchants nationally goes along with the supply chain management principle of simplifying the supply chain and reducing the supplier base as advocated by Jones (1990), Christopher (1992), Davis (1993), Tan et al. (1998). Kitter not only delivers the products on site, but prepare packs of products and then deliver them. All materials for low-value fit-out are distributed in 7 packs for masonry construction and only 4 packs for timber frame construction. Each pack is specifically aimed at different levels of construction of a house (starter pack, roof pack, first fix pack, etc.). For example, in pack number 5, items such as external doors, skirting, architrave, doorstop, internal doors, hinges and door latches and locks are packed together for a specific house type. The idea behind the use of packs is to reduce waste on-site arising from damaged, mislaid, and stolen material in the stockyard. That way, stock on-site can be minimised. Furthermore, it also reduces deliveries on-site as one delivery of packs is the equivalent of 6 deliveries. Finally it assures a faster assembly process as the whole kit is available at once and therefore all the parts needed for one part of the construction process are readily available. This concept of packs is similar to kitting which is found mainly in the electronic industry. Bozer and McGinnis (1984) define a kit as *"a specific collection of components and/or subassemblies with other kits (if any) support one or more assembly operations for a given product"*. The main reasons for using such a system include involve product structures with numerous parts or high-value components, of for the quality assurance of the assembly (Johansson, 1991).

The stock and flow diagram for making these packs is presented in Figure 9. "Making packs" variable takes into account the product coefficients for products A and B so as to ensure that the right quantities of each product are present in each pack.

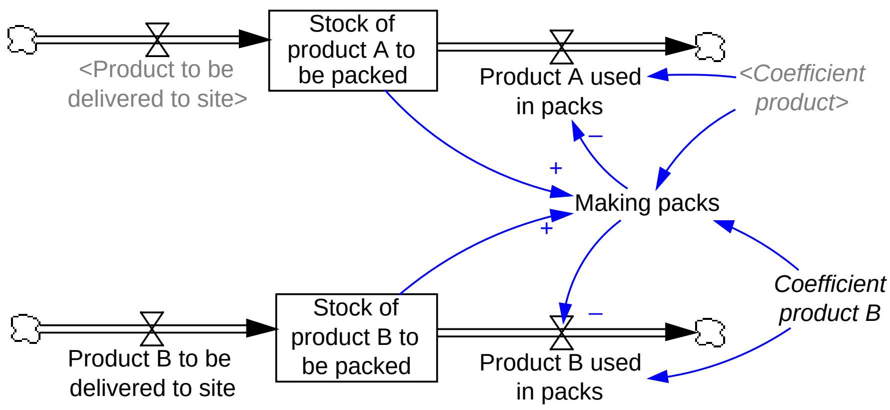
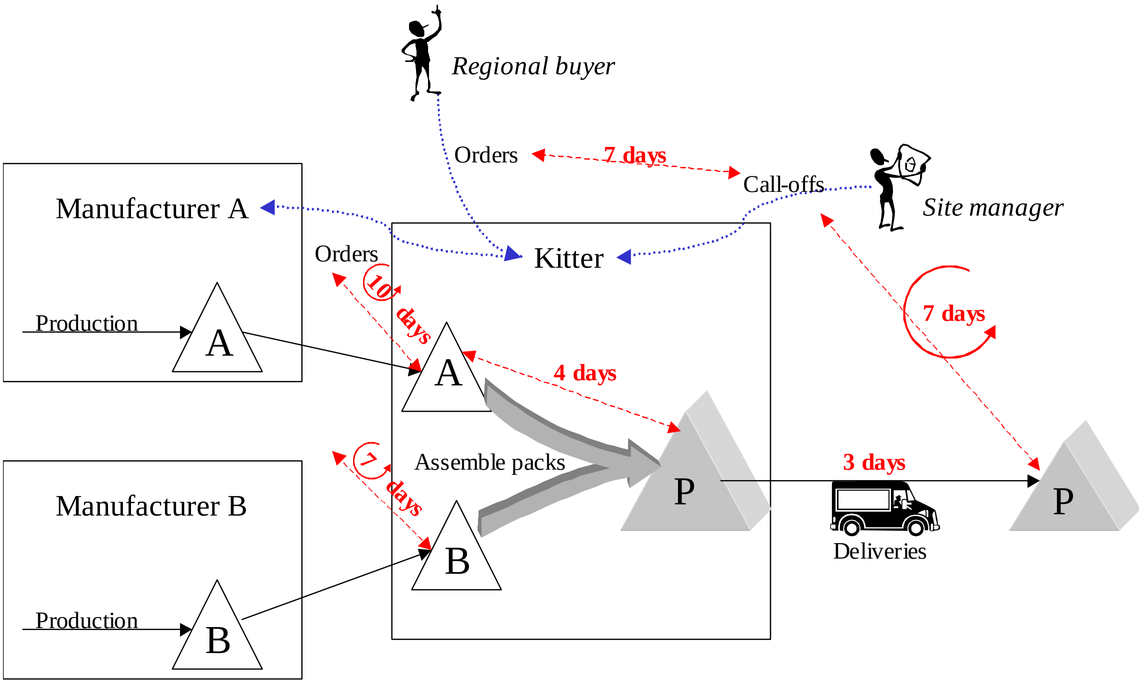


Figure 9 Stock and flow diagram for making packs by Kitter

Using Kitter allows a reduction from 14 to 7 days for delivery lead-time from the call off. This 7-day lead-time is made of 4 days to prepare the packs and 3 days for the delivery of the packs, as can be seen from Figure 10. Mistrust has been kept, but reduced to 75% because a lack of trust is still present as Kitter is only starting to operate.

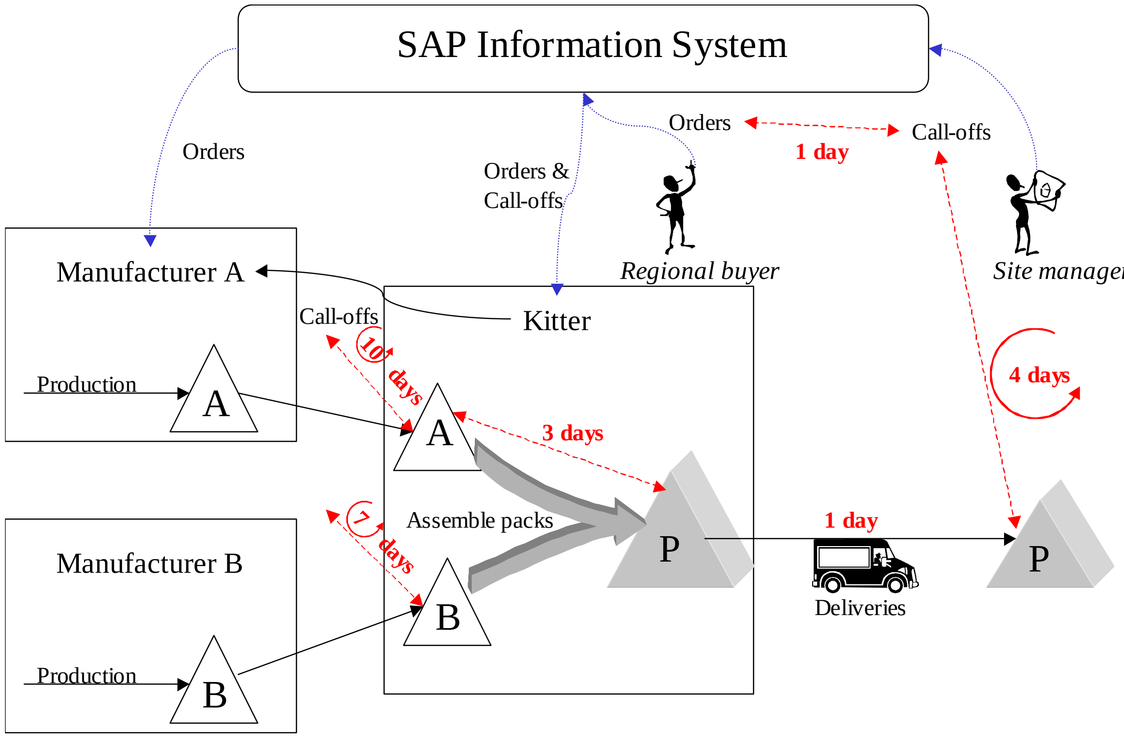


Where A represents doors and B skirting boards

Figure 10 Low-value fit-out supply chain using Kitter

Integrated Information scenario addresses the "Hot spots" 1, 2 and 3 (little visibility of long term market requirements by suppliers, very poor information transfer and use across the supply chain, and poor supplier delivery performance) by focusing on the information flow. One way to share information with several different organisations in a timely and accurate fashion is to use IT (Jones, 1990; Lee and Billington, 1992; Handfield and Nichols, 1999). In the case studied, the house developer decided to use the SAP/R3 system. The information system will be accessible by site managers, regional buyers, Kitter and manufacturers. The programme will be posted on the system and up-dated as required, therefore all the organisations involved will have access to accurate information on the site progress. Furthermore, the ordering and calling off processes will also be automated can carried out via the information system.

As the system has not yet been fully implemented, the settings presented here are based on the opinions of several managers working for the developer Home Builder and Kitter. It is expected that total order cycle time will be reduced to 5 days. One day advance notice before calling off the packs will suffice for Kitter (this is based on the assumptions that the house design is standardised and that Kitter is in possession of the drawings), therefore the packs could be assembled within 3 days. Finally, as can be seen from Figure 11, the delivery lead-time could be cut down to 1 day. This is already happening in most cases, the three days presented in the previous section being a buffer rather than a necessity. This buffer in planned time is common in the industry (Wegelius-Lehtonen and Pahkala, 1998).

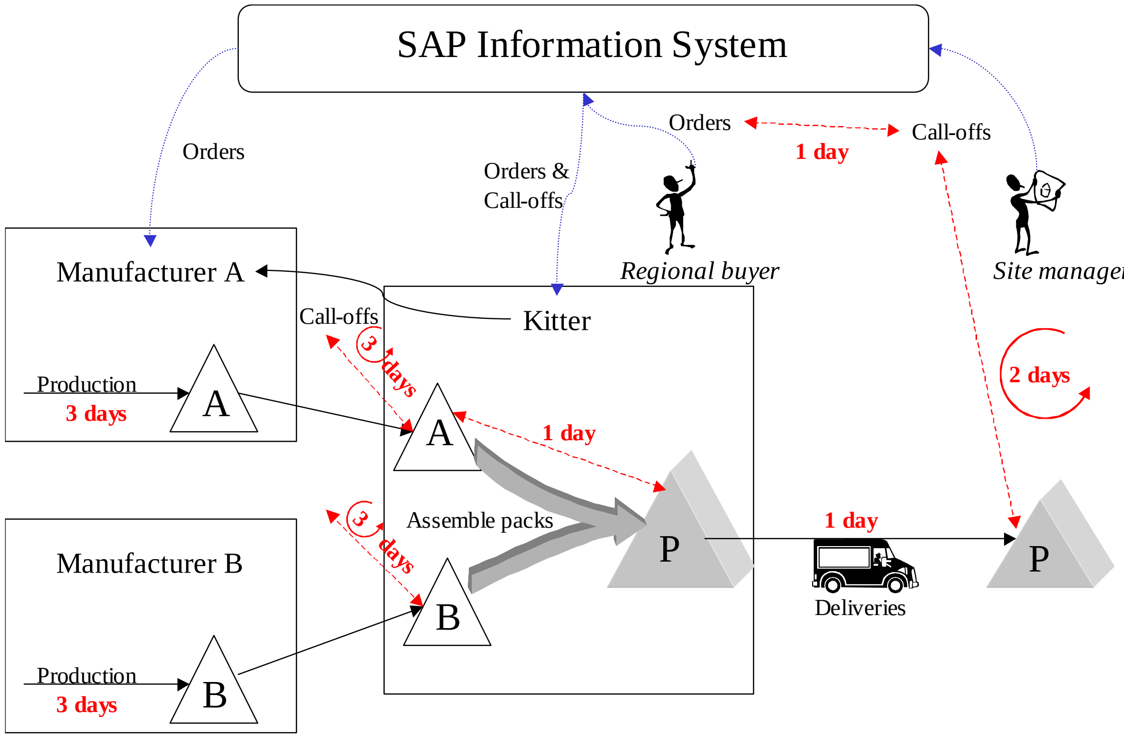


Where A represents doors and B skirting boards

Figure 11 Low-value fit-out supply chain with information integration

The information enrichment mechanism, as utilised by Mason-Jones (1998), was used with an information enrichment set at 50% in order to reflect the SAP system. This means that the manufacturer bases its requirements 50% on the original orders placed by the regional buyer and 50% on the orders received from Kitter. However, even though information is shared through the supply chain, it was agreed with the interviewees that mistrust should still be set at 50% as trust is slowly building up between companies but they are not yet ready to trust each other fully.

Synchronised scenario investigates the impact of synchronisation of lead-times in the supply chain (Stevens, 1989; Sabath, 1995; Towill, 2000). This scenario was developed with the collaboration of the procurement manager from Kitter. Once Kitter is working at full capacity and the SAP system is implemented and in use, Kitter will be able to reduce their lead-times further to achieve a total order cycle time of 3 days as shown in Figure 12. Pack assembly will only require 1 day, the personnel will have gone through a learning curve and as the house design will be standardised, variations from one pack to another should be limited. It will still be necessary to allow one day for the transfer of packs to site. As the relationship with the manufacturers should have shifted from being adversarial to being more collaborative and partnering, and as the manufacturers will have access to up-to-date information from the information system, the total order cycle time will be reduced to 3 days. This means that the different organisations in the supply chain will work on the same 3-day order cycle time and therefore will be synchronised. The mistrust is therefore set at 0% and the information enrichment at 75%, which is, according to Mason-Jones (1998), one of the best settings.



Where A represents doors and B skirting boards

Figure 12 Synchronised low-value fit-out supply chain

Summary of the re-engineering scenarios and parameters setting

Table 3 summarises the four scenarios for the low-value fit-out supply chain in terms of supply chain structure, the involvement of each agent, the type of innovation introduced and the total order cycle time.

Scenarios	Baseline	Kitter	Integrated information	Synchronised
Supply chain structure	Developer, multiple merchants, manufacturers	Developer, single merchant, manufacturers		
Developer	Order from merchants	Order from Kitter		
Merchants / Kitter	Order from manufacturers	Order from manufacturers and prepare packs		
Manufacturers	Deliver to merchants	Deliver to Kitter		
Innovation	-	Use of Kitter	Use of an information system across the supply chain	Synchronised lead-times across the supply chain
Total order cycle time	21 days	14 days	5 days	3 days

Table 3 Summary of the re-engineering scenarios

The initial values, parameters and sources for the low-value fit-out scenarios are presented in Table 4. Cost in stock equals 0.5 and costs stock out equals 1 for two units of product A or 140 units of product B.

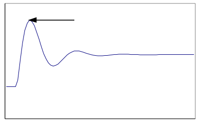
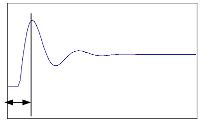
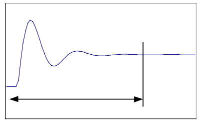
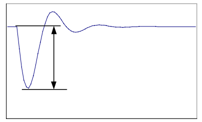
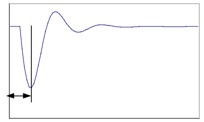
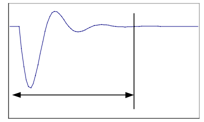
Parameters	Value for Baseline	Value for Kitter	Value for Integrated Information	Value for Synchronised	Source
Home Builder					
Coefficient product A/B	2/140	2/140	2/140	2/140	Judgementally set based on interviews
Order to call off delay	7 days	7 days	1 day	1 day	Set based on interviews
Call off to delivery delay	14 days	7 days	4 days	2 days	Set based on interviews
Merchants					
Coefficient Merchants A	0.3; 0.05; 0.1; 0.1; 0.03; 0.2; 0.12; 0.1	0.3; 0.05; 0.1; 0.1; 0.03; 0.2; 0.12; 0.1	-	-	Judgementally set based on interviews
Coefficient Merchants B	0.2; 0.1; 0.1; 0.12; 0.05; 0.3; 0.1; 0.03	0.2; 0.1; 0.1; 0.12; 0.05; 0.3; 0.1; 0.03	-	-	Judgementally set based on interviews
Mistrust coefficient	1	0.75	0.5	0	Judgementally set based on interviews
T_a merchants A/B	20/14	20/14	20/14	6/6	Based on Towill and Del Vecchio (1994)
T_i merchants A/B	20/14	20/14	20/14	6/6	Based on Towill and Del Vecchio (1994)
Transport delay A/B	10/7	10/7	10/7	3/3	Set based on interviews
Merchant actual inventory	4* average orders	4* average orders	4* average orders	4* average orders	Set based on interviews
Merchant target inventory	4*average orders	4*average orders	4*average orders	4*average orders	Set based on interviews
Manufacturer					
T_a manufacturer A/B	20/14	20/14	20/14	6/6	Based on John et al. (1994)
T_i manufacturer A/B	10/7	10/7	10/7	3/3	Based on John et al. (1994)
Production delay A/B	10/7	10/7	10/7	3/3	Set based on interviews
Manufacturer actual inventory	4*average orders	4*average orders	4*average orders	4*average orders	Set based on interviews
Manufacturer target inventory	4*average orders	4*average orders	4*average orders	4*average orders	Set based on interviews
Information enrichment coefficient	0	0	0.5	0.75	Judgementally set based on interviews and Mason-Jones (1998)
Measure of performance					
Cost in stock A/B	0.25/(0.5/140)	0.25/(0.5/140)	0.25/(0.5/140)	0.25/(0.5/140)	Arbitrary set
Cost stock out A/B	0.5/(1/140)	0.5/(1/140)	0.5/(1/140)	0.5/(1/140)	Arbitrary set

Table 4 Parameters, initial values and sources for low-value fit-out scenarios

Simulation results

Each scenario has been simulated daily for a step change in demand over a period of 3 years. The step change in demand increased from 100 to 120 houses at day 20.

First of all, it is interesting to analyse the ranking of the scenarios for the step change in demand, taking into consideration the six dynamic criteria presented earlier. Using a linear scale where four stars is best and one star worst, the results presented in Table 5, represent the response at manufacturer level. For ease of presentation, only the door manufacturer response is presented. It can be seen that Synchronised scenario achieves the best overall performance, followed by Baseline scenario. Integrated Information scenario achieves the worst performance for Peak value, while Synchronised scenario registers the worst performance for stock depletion, which can be explained by the short lead-times. However, Synchronised scenario achieves the best performance for peak time and trough time as its lead-times are much shorter.

Scenarios	Peak Value 	Peak Time 	Order Recovery 	Stock Depletion 	Trough Time 	Stock Recovery 	Scenarios Performance
Baseline	****	*	**	****	*	****	***
Kitter	**	**	*	***	**	**	*
Integrated Information	*	***	****	**	***	*	**
Synchronised	***	****	***	*	****	***	****

*Where **** represents the best performance and * the worst*

Table 5 Ranking of the different scenarios for dynamical performance criteria at the manufacturers for step change in the demand

The dynamic performance assessed using the 6 criteria above, can be summarised using only two criteria, the production on-costs and integrated absolute error (IAE) for the inventory level of the manufacturers. Furthermore, the total supply chain inventory costs has been calculated using the simulations. Table 6 presents the ranking of the scenarios using these three performance criteria.

Scenarios	Production on-costs	IAE inventory	Total SC inventory costs	Scenario performance
Baseline	***	****	*	***
Kitter	*	**	***	*
Integrated Information	**	***	****	****
Synchronised	****	*	***	***

Where **** represents the best performance and * the worst

Table 6 Scenarios' ranking for a step change in demand

The production on-costs are minimised in the case of Synchronised scenario, which means that Synchronised scenario achieves the smallest demand amplification of the four scenarios. Baseline scenario registers the worst results in terms of total supply chain inventory costs. It could be suggested that this is due to the large number of merchants, however, the stock level for each merchant was set at four times the average demand, knowing that the total demand placed on the merchants is the same as for Kitter. Therefore, the high level of total supply chain inventory costs has to be explained by the behaviour of the model itself. Furthermore, it must be noted that in real life, the level of safety stock for Kitter would be based on the square root law (Maister, 1976) and therefore could be reduced by a further $\frac{\sqrt{1}}{\sqrt{8}}*100 = 35.35\%$.

In order to understand the above results better, *the magnitude of the impact* that each scenario has on performance needs to be looked at. The impact of the scenarios in comparison with Baseline scenario is presented in Table 7. It can be seen, that the total supply chain inventory costs is reduced for all three scenarios in comparison with Baseline scenario. Furthermore, Synchronised scenario improves the production on-costs by 30% in comparison with baseline scenario. Finally, all three scenarios increase the IAE for inventory in comparison with Baseline scenario, especially Synchronised scenario with a 16% increase.

Scenarios	Production on-costs	IAE inventory	Total SC inventory costs
Kitter	+22%	+10%	-0.8%
Integrated Information	+21%	+6%	-1.1%
Synchronised	-30%	+16%	-0.8%

Table 7 Impact of the scenarios on performance criteria in comparison with Baseline scenario for a step change in demand

The results for the four strategies for a step change in demand have been analysed. However, the impact of each SCM principle cannot be fully understood as more than one parameter has been changed from one scenario to the next. Therefore, further simulations have been carried out to analyse the impact of every single change (called strategy) made, to move from one scenario to the next, in the case of a step change in demand.

Baseline - Kitter

The first comparison has been carried out between Baseline scenario and Kitter scenario. Here the SCM principles implemented were the centralisation of supply, the total cycle time reduction and improved relationships between the trading partners. This was simulated by:

- Replacing the merchants by Kitter: “No merchant” strategy
- Reducing the lead-time from order to call off from 14 to 7 days: “Delay call off” strategy
- Taking material out of stock earlier, in order to assemble packs, from 1 to 8 days: “From stock” strategy
- By reducing the mistrust level between the regional buyer and the merchants from 100% to 75%: “Mistrust customer” strategy
- By reducing the mistrust level between the merchants and the manufacturers from 100% to 75%: “Mistrust merchants” strategy

Table 8 presents the amplitude of impact that each strategy has in comparison with Baseline scenario. “No merchant” strategy improves both production on-costs (by 38%) and IAE inventory (by 11%), which means that it improves the dynamic behaviour. Therefore, moving away from multiple merchants on a regional basis to use one single company on a national basis, not only improves the dynamic performance but also the total supply chain inventory costs. This confirms Charatan’s (1999) observation that centralisation on a national basis of supply has almost always been beneficial. However, reducing the lead-time between order and call off has a negative impact on the dynamic behaviour; this is understandable as “advance notice” of what is going to be called off is shorter and therefore manufacturers have less time to react to changes in demand.

Scenarios	Production on-costs	IAE inventory	Total SC inventory costs
No merchants	-38%	-11%	-0.2%
Delay call off	+65%	+14%	-0.2%
From stock	+77%	+17%	-0.2%
Mistrust Customer	(-1%)	(-0.2%)	(+0.001%)
Mistrust Merchants	(-0.01%)	(+0.3%)	(-0.001%)
Kitter	+22%	+10%	-0.8%

Table 8 Impact of each strategy from Baseline scenario to Kitter scenario

In a similar manner, "From stock" strategy worsens the dynamic behaviour as materials are taken from stock earlier on and thus the manufacturers do not have as much time to build up their stock against the increase in demand. All three strategies ("No merchant", "Delay call off", and "From stock") reduce the total supply chain inventory costs, which explains the impact on that same criteria by Kitter scenario, as it is the combination of these strategies.

Finally, the impact of "Mistrust" strategies is indicated in brackets as it only has a marginal impact and does not refer to the same starting level of stock than for the other scenarios. However it gives an interesting insight into the way in which the reduction of the mistrust level, or in other words, the increase of trust between trading partners, affects performance. Interestingly, "Mistrust customer" increases the total supply chain inventory costs, while "Mistrust merchants" reduces it. Therefore, when the level of mistrust is reduced between the site and the merchants, the total supply chain inventory costs increase, while the dynamic performance at the manufacturer level improves. This can be explained by the fact that less disturbance or noise is present in the demand signal received by the manufacturers.

The reduction of mistrust between merchants and manufacturers improves production on-costs but increases IEA inventory. This can be explained by the fact that as mistrust diminishes, the demand received by the manufacturer is lower (only 75% of the product quantities that have not been received is added to the demand instead of 100%). However, it also means that the manufacturer does not overproduce and therefore its stock level diminishes more rapidly.

Kitter – Integrated Information

Next, the scenarios Kitter and Integrated Information can be compared. Here the SCM principles implemented were the use of an information system to share end-customer demand, reduction of total cycle time and improved relationships between trading partners. These principles were implemented by:

- Passing on the site demand to the manufacturers. The manufacturers base their requirements 50% on the site demand and 50% on the orders received from Kitter: "Information enrichment" strategy

- Reducing the lead-time from order to call off from 7 days to 1: “Delay call off” strategy
- By reducing the mistrust level between the regional buyer and Kitter from 75% to 50%: “Mistrust customer” strategy
- By reducing the mistrust level between Kitter and the manufacturers from 75% to 50%: “Mistrust Kitter” strategy

As presented by Mason-Jones (1998), the implementation of an information enrichment mechanism improves the dynamic behaviour. It also reduces the total supply chain inventory costs. As seen previously, “Order to call off” has a negative impact on the dynamic behaviour (by increasing both production on-costs and IAE doe inventory) but improves the total supply chain inventory costs.

Here again, reducing the mistrust level from 75 to 50% increases the total supply chain inventory costs (Table 9). The marginal increase of IAE for inventory of “Mistrust customer” is due to a greater drop in inventory level in the case of 50% mistrust, however as there are fewer disturbances in the demand signal, the inventory level recovers more rapidly.

Scenarios	Production on-costs	IAE inventory	Total SC inventory costs
Information Enrichment	-21%	-13%	-0.1%
Order to call off	+13%	+8%	-0.2%
Mistrust Customer	(-4%)	(+0.1%)	(+0.1%)
Mistrust Kitter	(+0.1%)	(-2%)	(+0.01%)
Integrated Information	-1%	-3%	-0.4%

Table 9 Impact of each strategy from Kitter scenario to Integrated Information scenario

The increase in production on-costs for “Mistrust Kitter” is explained by the fact that the production level peaks higher than for 75% mistrust. The marginal reduction of IAE for inventory is due to a smaller trough in inventory level.

Integrated Information - Synchronised

Finally, Integrated Information and Synchronised scenarios can be compared. The SCM principles implemented are the same as from Kitter to Integrated Information scenarios, i.e. the use of an information system to share end-customer demand, reduction of total cycle time and improved relationships between trading partners. These principles were implemented by:

- Passing on the site demand to the manufacturers. The manufacturers base their requirements 75% on the site demand and 25% on the orders received from Kitter: “Information enrichment” strategy
- Reducing the manufacturing lead-times from 10 to 3 and 7 to 3 days for Manufacturer A & B respectively: “Manufacturers lead-time” strategy

- By abolishing mistrust between the regional buyer and Kitter (from 50% to 0%): “Mistrust customer” strategy
- By abolishing the mistrust between Kitter and the manufacturers (from 50% to 0%): “Mistrust Kitter” strategy

“Information enrichment” reduces production on-costs by 9% and the total supply chain inventory costs (Table 10). The reduction of manufacturing lead-times reduces the production on-costs by 36%, however the IAE for inventory is increased due to a lower trough. “Mistrust customer” reduces both production on-costs and IAE inventory; this is due to the fact that in both cases, it recovers more quickly, whereas “Mistrust Kitter” increases both dynamic criteria. In this case, it peaks later and attains a lower trough in inventory level.

Scenarios	Production on-costs	IAE inventory	Total SC inventory costs
Information Enrichment	-9%	+3%	-0.1%
Manufacturers lead-time	-36%	+11%	+0.4%
Mistrust Customer	(-7%)	(-2%)	(+0.3%)
Mistrust Kitter	(+0.01%)	(+2%)	(+0.01%)
Synchronised	-42%	+9%	+0.4%

Table 10 Impact of each strategy from Integrated Information scenario to Synchronised scenario

Conclusion

It was seen that the private house building industry in the UK is not performing and that due to increased governmental pressures and change in environment, the house building industry will have to improve its performance if it is to survive. This paper then focused on dynamic performance and on total supply chain inventory costs. Four scenarios for the low-value fit-out supply chain have been presented and simulated. It was seen that supply chain management principles can be utilised to improve performance.

The most important lessons learnt from the simulations are, first of all, that Integrated Information scenario achieves the best overall performance for a step change in demand, while Baseline and Kitter scenarios achieve the best overall performances for a random change in demand. For both demand inputs, all three scenarios – Kitter, Integrated Information, and Synchronised – improve the total supply chain inventory costs in comparison with Baseline scenario.

Using one single national merchant instead of several regional merchants improves all three performance criteria (production on-costs, IAE inventory and total supply chain inventory costs). This concurs with Charatan’s (1999) and Henkoff’s (1994) observations on the positive impact of centralisation of supply. Reducing the delay between placing an order and the call off, has a negative impact on dynamic performance. This is also the case for "From stock" strategy, which takes material out of stock several days before delivery. Information enrichment improves the performance criteria studied (Mason-Jones, 1998), while reducing manufacturing lead-times has a detrimental effect on the total supply chain inventory costs and IAE for inventory. However, it has a positive effect on production on-costs.

Finally, reducing mistrust either between customer and merchants/Kitter, or between merchants/Kitter and manufacturers, has a positive effect in terms of faster recovery to a stable state. However, in all cases, reduction of the mistrust level between trading partners increases the total supply chain inventory costs.

In conclusion, it can be seen that the house building industry has the opportunity to learn from other industries by, for example, using supply chain management principles to improve its performance.

Acknowledgements

This paper highlights work undertaken during an EPSRC IMI and DETR funded research project as part of a LINK programme on Meeting Customer Needs through Standardisation. The sponsorship and the time and effort made available by the industrial partners is gratefully acknowledged. Thanks also to Prof. D. Gann, Prof. J. Barlow, Dr. R. Ozaki, P. Childerhouse and Dr. M. Naim who were fellow research members on the project.

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