The difficulties of matching supply and demand due to the inherent dynamics within a supply chain structure are a long standing and widespread problem. Market sales information notoriously suffers from delay and distortion as it moves upstream through the supply chain. This results in production profiles at the factory, which bear little resemblance to the end consumer’s buying behavior. This phenomenon was demonstrated nearly forty years ago by Jay Forrester [1]. Unfortunately, real world supply chains today are still suffering the often-painful effects of upstream order magnification and by much greater ratios than experienced in the original Forrester simulations [2]. A good illustration of the Forrester Effect in action as presented by Fine [3] is shown in Figure 1. Quite apart from the order magnification as it passes upstream, it should be noted that other important supply chain behavioral phenomena are also evident. These refer to the geographical (frequently by many miles) and temporal (usually by many months) separation of cause and effect within this volatile dynamic system. Given such masking of what is happening at the marketplace, the need for transparent information flow is paramount. It is therefore not surprising that it should be at the heart of many successful BPR Programs as typified by the Carpenter Technology Case Study [4].

Effective supply chain management requires companies to develop innovative strategies that integrate both their logistics and manufacturing activities [5]. The concept of postponement has been utilized effectively by supply chains as a way of limiting the effect of the debilitating inherent system dynamics on their ability to meet customer demands. Postponing the variant differentiation of a product until the latest possible moment reduces the risk and uncertainty imposed by the consumer demands. An example is in paint manufacturing business, where rather than holding stocks of a whole range of colors, which then requires a fair amount of forecasting to ensure the right colors are available, the paint is produced as a neutral base and color added only on consumer demand at the time of sale.
order [5]. Thus, postponement of stages of manufacture enables a supply chain to be more reactive to real changes in consumer demand. Hence, the product should remain generic thereby postponing customization for as long as possible [6].

The postponement strategy requires very careful thought as to the placement of the material decoupling point. This basically establishes a strategic stock that acts as a planned buffer between each side of the supply chain. Such strategic placement of the material decoupling point enables supply chains to cushion the upstream companies from the fluctuating consumer demand thus minimizing some of the self defeating dynamics already met in Figure 1. All supply chains have two distinct and basic flows, known as the material pipeline and the information pipeline respectively. However, the traditional decoupling point approach only addresses the material flow pipeline. But one of the key sources of supply chain dynamic magnification is the order information distortion as it flows upstream. The authors have taken the decoupling point methodology, which is traditionally associated with material flow, and adapted it to the information flow pipeline. Information circulation within the supply chain is not a new idea. What is proposed here is its formalization within the decoupling point concept.

Improved information flow is made possible by EDI. This may be implemented in three distinct ways [7]: by automating traditional, arms-length supply chains; by linking all companies in the chain directly with the marketplace; and by linking all companies in the chain, but implementing holistic control over the complete system.

Through a generic simulation model typical of many real world supply chains the authors show that in the absence of holistic control to maximize performance improvement the information decoupling

![Figure 1: The Supply Chain Bullwhip Effect](source.png)

point needs to be positioned as far upstream as possible, which is by linking all companies in the chain directly with the marketplace. This contrasts with the situation where the material decoupling point is placed as close to the end consumer as possible dependant only on the product type, degree of customization, and supply chain strategy adopted. The strategic implications of the information decoupling point are discussed herein and the dynamic performance improvements available via repositioning it upstream are analyzed and demonstrated to substantially reduce wave form propagation. Indeed for the industrial example quoted, the benefit is virtual level scheduling at the factory, but is additionally coupled with adequate automatic trend detection.

Information is a Supply Chain Commodity

Supply chains have at least two distinct flow pipelines: the order information transfer pipeline, from point of sale through to raw material supplier; and, the product transfer pipeline from raw materials to end customer. Production is activated by demand information therefore speed and fidelity of order data transference is crucial to enabling good supply chain dynamics. Figure 2 shows the characteristic “U” shape of the total lead-time pipeline through a simple, four stage, linear supply chain. It connects end consumer demand to goods delivery into the marketplace with orders following upstream and products flowing downstream. Models of such apparent simplicity have been shown to generate improvement strategies, which work on real world supply chains [8]. Such validated models also produce outputs, which match those of the physical system [9]. Furthermore, the network interference effects due to value streams competing for the same resources are readily incorporated in simulation experiments [10].

Many companies have concentrated improvement strategies within the material flow pipeline. This is because it is much simpler to re-engineer the shop floor under our control and chase improvement from immediate suppliers than it is to seriously practice total supply chain management as required to redesign the information flow pipeline. However, Braithwaite [11] warned of the futility of concentrating on just one pipeline alone. He quoted the example of a company striving to reduce manufacturing cycle times by just one day while not attempting to tackle two to three week ordering delays. In such circumstances customer service levels remain relatively untouched after what may be frenzied shop floor reorganization and with no significant impact on the cash cycle either. To fully realize performance improvement potential, supply chains need to develop integrated strategies for both information and material flow pipelines.

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interface dealing with the end customer. However, in many supply chains only the player closest to the end customer has the luxury of knowing the true demand because the information decoupling point is traditionally at the marketplace – retailer position. The question is how can this rich information resource be strategically used to improve dynamic performance of the supply chain. If the order decisions within each player in the supply chain could be enriched with the undistorted market sales data via moving the information decoupling point upstream, the information distortion and wave form propagation often exhibited in the real world could be greatly reduced. This would beneficially impact the behavior of both ordering and stock level dynamics from an individual business and from a total supply chain perspective level [12].

Lipton, discovered the importance of strategically utilizing information for successful supply chain management [13]. During a lessons learned analysis conducted after adopting an Efficient Consumer Response (ECR) approach at Lipton, three key components were identified as appropriate to all levels of the supply chain: competing on capabilities; changing the way goods are priced; and changing the way information is viewed and used.

Unfortunately, sharing in-depth information sounds easy, but does not come naturally for most companies. In fact, company policy has in the past frequently actively discouraged it [14]. Information has traditionally been perceived to be power, that is, those with the knowledge have a strategic advantage. The traditionally adversial relationships between supply chain members where they regard each other as enemies does not help anybody except competitors [15]. The information decoupling point thereby acts as a buffer between upstream and downstream players in the supply chain. This enables upstream players to be protected from fluctuating consumer buying behavior therefore establishing smoother upstream dynamics while downstream consumer demand is still met via a product pull from the buffer stock. Figure 3 summarizes in flow diagram from the foregoing material pipeline decoupling point definition.

The material flow decoupling point can also be used to establish a postponement strategy. Postponement basically moves product differentiation as close to the end consumer as possible via a strategic stock at the material decoupling point. The supply chain can produce a generic product for as long as possible, thereby further smoothing the upstream dynamics via reduced product variety enabling the chain to both respond faster to consumer demands and limit the effect of obsolete stock. For example, companies such as Hewlett-Packard have capitalized on moving the material decoupling point close to the customer by producing generic printers and only regionally customizing them at the distribution centers as opposed to within the manufacturing plants [18].

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chain strategies as defined by Pagh and Cooper, [19] which are available by altering the position of the material decoupling point. These strategies range from providing highly customized products, which have high uncertainty (full postponement strategy) through to providing a standard product with low demand uncertainty (full speculation strategy). Despite the fact that the material decoupling point for each of the previously mentioned postponement strategies are at different points of the supply chain, the governing principle is always to move the material decoupling point as close to the end consumer as possible thereby ensuring the shortest lead-time for the consumer. This approach also enables full capitalization of the benefits of divorcing the customer variability from the demands placed on the majority of players in the supply chain.

The Information Decoupling Point

As previously stated, there are a minimum of two pipelines within the supply chain; the material flow and the information flow. The authors argue that both flows have their own significant decoupling point, the strategic use of which differs due to the dynamic effect each has on the performance of the supply chain, Mason-Jones and Towill [20]. Hence, each supply chain has both a material decoupling point and an information decoupling point each of which is a separate entity. Only by recognizing this and strategically positioning both can full performance improvements be realized. However, due to the differences in the two pipelines the information decoupling point requires a definition of its own and is defined by the authors as follows:

The point in the information pipeline to which the marketplace order data penetrates without modification. It is here where market driven and forecast driven information flows meet.

The order information pipeline decoupling point is the point at which information turns from the high value actual consumer demand data to the typical upstream distorted, magnified and delayed order data. Traditionally, in supply chains this tends to be placed at the same point as the material decoupling point and is therefore placed as close to the end consumer as possible. This positioning is very wasteful and limits the effectiveness of the high value resource of undistorted order information available on the dynamics of the supply chain. Therefore to maximize the strategic potential of these data within the supply chain, in direct contrast to the material decoupling point, the information decoupling point should be moved as far upstream as possible. This enables upstream players to include within the ordering decisions the unbiased undistorted, rich information that is already available downstream. There will be greater upstream market order penetration while leaving the point at which the supply chain directly responds to the customer (the material decoupling point) intact. Figure 5

...each supply chain has both a material decoupling point and an information decoupling point each of which is a separate entity.
summarizes this perception of the two decoupling points and their relative positions within the supply chain structure.

Theoretically, the argument for moving the information decoupling point upstream in order to give more players the benefit of having undistorted data appears quite clear and straightforward. However, the question that needs to be answered here is how the information decoupling point is moved and what will be the effects on the dynamic responses of the supply chain. Our view is that transparency of information is the vital step forward. How frequently it should be sampled and used for delivery and capacity planning depends on the individual business. For example, a supplier to a supermarket may receive hourly point-of-sale data, but plan capacity over a weekly horizon. But it can make such planning decisions far better on the basis of an undistorted view of what is really happening in the marketplace. Indeed, this information would be fundamental in any Continuous Replenishment Program [21].
Simulating the Information Decoupling Point

The use of simulation as a systems engineering analysis tool to research and understand the impact of supply chain dynamics on business performance was established 40 ago by Jay Forrester [22]. Simulation models are widely regarded as good demonstration vehicles for design and development of system design strategies by management consultants [23]. They also support general redesign principles, which may be applied to a wide range of real world supply chains [24]. The information decoupling point simulation model used here is based on the well documented Automatic Pipeline Inventory Order Based Production Control System (APIOBPCS) [25]. This in turn embraces a number of control structures proposed elsewhere in the literature [26]. The corresponding simulation model order decision rule for each echelon of the supply chain is represented in causal loop format in Figure 6 [26].

Many supply chain dynamics scenarios can be adequately mimicked by using the APIOBPCS format to represent the activities at each echelon within the chain. By careful selection of parameters, each echelon can be simulated with decision rules ranging from level scheduling; make-to-stock; passing on orders; through to fully integrated
order/stock control policies. Such a simulation model has been many times verified on real world supply chains including the electronics products industry and the automotive industry [28]. The APIOBPCS based simulation model may be used confidently as a benchmark to demonstrate performance enhancement for a wide range of practical supply chains. Note from the Causal Loop Diagram that we have the freedom to mix the marketplace information with our direct customer orders in any combination we wish. The important point is that by minimizing downstream order uncertainty, we have the data needed to make an informed judgement [29].

The demonstrator model utilized is a four level supply chain constituting a retailer, distributor, warehouse and factory. For convenience, the material flow lead times are set the same at each stage. If anything, due to the presence of resonance effects, such equality tends to highlight potential areas for performance improvements [30]. Figure 7 shows a representation of the optimized order information pipeline. This adaptation we call the information enrichment model, and it is achieved via an electronic point of sales link (EPOS) to all players down stream of the information decoupling point. This enables all such players to have an undistorted view of the consumer buying behavior thereby enabling the supply chain to operate effectively without the added burden of the distortion of end customer demand characterized by the Forrester Effect.

In order to analyze the strategic benefits of the information decoupling point and determine where in the supply chain its optimal position might be, four competing designs were simulated. Figure 7 illustrates the selected relative information decoupling point positions in the supply chain. Design 1 simulates the traditional supply chain where only the retailer accesses the actual buying pattern. This design provided data against which the other designs could be benchmarked. Design 2 and 3 test the dynamics of the supply chain as the information decoupling point is moved further upstream enabling an increasing number of players to utilize the consumer sales information. Finally, Design 4 analyzes the potential dynamic improvements available if the information decoupling point is moved to the furthest point upstream thereby enabling all four members of the supply chain to have a direct line of sight to the consumer.
We find that for synthesis purposes it is easiest to use a step demand to simulate a shock event at the marketplace. Analyzing the response to a step increase in demand in the marketplace is an essential starting point when simulating a supply chain because of the relative ease of analysis and the extensive background of previous research. The reason for this is that the step response provides an extremely rich picture of the supply chain dynamics and which can be used as a predictor of system behavior under a wide range of circumstances. Therefore, the simulation model was injected with a 20% step increase in consumer demand for each of the designs to be tested. Using the step response as a performance benchmark it is possible to thereby predict system responses for a wide range of operating scenarios. [31].

Moving the Information Decoupling Point to Maximize Competitive Opportunity

The dynamic behavior of the supply chain for each of the four designs was assessed and analyzed via the order rate and stock level behavior patterns at each echelon. Since it is the factory which experiences the worst buffeting in a traditional supply chain, this would appear to be an important statistic for measuring the improvement in dynamic behavior of the whole chain. The peak factory order rate is a simple but realistic performance metric since improvement here will benefit the whole chain.

The percentage of improvement of the factory order rate for each of the four designs is summarized in Figure 8. For convenience, the improvement scale selected is linear and in the range 0% for the datum design to 100% for the idealized best imagined dynamic response. Using such a linear scale gives a very conservative estimate of likely performance improvement. What is clear from the simulation results is that the further the information decoupling point is moved upstream the better the improvement in the dynamic behavior of the supply chain, as observed via factory order rate. This is due to improved knowledge of the actual end consumers buying behavior via a direct link to the marketplace for all players downstream of the information decoupling point.

The delay of initial response to a change in the marketplace experienced by the baseline traditional supply chain (Design 1) is reduced through strategic use of the information decoupling point. The further upstream it is placed, the more stages of the supply chain have unbiased data of the consumers’ buying pattern, and can further help to improve the dynamic response of the whole chain. When the information decoupling point is placed at the factory, the potential performance improvement due to this particular action is maximized; Figure 8 shows a gain of 80% of the theoretical best attainable dynamic performance. This is because the whole chain begins to respond to a consumer change as soon as it happens since the factory can see changing consumer habits as they occur. This is in contrast to the much smaller benefit gained when the information decoupling point is placed at the distributor, as might be the case for Vendor Managed Inventory (VMI). But with full disclosure upstream, players can now endeavour to plan ahead and pre-empt future dispatch fluctuations, thereby reducing the distortion effects. Hence, via the strategic placement of the information decoupling point at the furthest point upstream, the factory is able to make an informed decision at a much earlier point in time than the factory at the end of the traditional supply chain.

Using Both Decoupling Points: An Industry Example

More companies are becoming aware of the dynamic benefits available via better use of the information within the supply chain. Some organizations make the mistake of thinking that adopting Information Technology (IT) is in itself sufficient to realize the available benefits. But IT is an enabler and must be utilized properly, and in itself is not the total answer [32]. While managers in many companies see the need for information transparency perhaps less have realized that what they need is a policy on the strategic placement of the information decoupling point. The optimal place for the information decoupling point is at the furthest point upstream possible, thereby, enabling the maximum number of members in the chain to...
have available the actual marketplace information for better forecasting and decision making.

This section summarizes a substantial reengineering program aimed at streamlining an electronics products supply chain, which included a strategic placement of both the material and information decoupling points [33]. The process of supply chain redesign consisted of a series of overlapping business process reengineering (BPR) programs that began in the early 1980's and which continue to be enabled through to the present day. As part of its BPR initiative, the electronics products company concentrated the later stages on establishing and strategically placing both a material and an information decoupling point. The optimized strategy is illustrated in Figure 9 where the positioning of both decoupling points can be clearly identified in what has since become recognized as the legal supply chain [34]. As can be seen, the material decoupling was placed as close to the consumer as possible (at the finished goods assembler), while available postponement opportunities were maximized. The information decoupling point was placed as far upstream as possible, thereby communicating the actual consumer demand direct to the components assembler. The component assembler is forewarned of changes in sales profile and is able to meet the necessary demands of the supply chain.

The company's BPR program was carried out in four key stages as identified in Figure 10. Each stage of the BPR program actively improved the dynamic performance of the supply chain. The dynamic improvements estimated via the verified aggregate product six-echelon simulation model realized for each BPR stage is summarized in Figure 10. Although in practice some BPR stages overlapped, for the purpose of illustration the simulation is based on sequential implementation. For consistency, judgements were made on the basis of dynamic response at the most upstream echelon to a step change in the marketplace. The linear scale was selected so that 0% is the base point and 100% is the idealized best possible response. Once all four stages of improvement were completed, the supply chain model predicted an impressive resulting estimated dynamic improvement of 92% in comparison to its initial baseline performance. The final system design eventually generated the desirable upstream pattern of virtual level scheduling. At the same time the system retains the highly desirable automatic trend following capability throughout the chain.

What is apparent from Figures 9 and 10 is that the latter two stages of the BPR program involve establishing and strategically placing both material and information decoupling points. The utilization of both the EDI enabled information decoupling point (which occurs in stage D) and product design material decoupling point (stage E) approaches enabled the supply chain to further improve its dynamic performance due to these sources alone by approximately 42% as shown in Figure 10. In this supply chain information transparency was in place before
finalization of the material flow decoupling point in its present form. This is because in the electronic products supply chain, the material flow decoupling point location is heavily dependent on product design [35], which generally takes longer to achieve, compared to the installation of EDI. It is the combination of information transparency and product modularization that enables mass customization [36].

**Conclusion**

Supply chains are constructed around two principal pipelines: the information and material flows. These require operational strategies, which are sympathetic and which integrate and compliment the individual characteristics of both pipelines. The decoupling approach has been successfully utilized within the material pipeline by many companies. However, utilizing a decoupling point can create benefits in the information flow pipeline. The information decoupling point is the point in the supply chain at which the order information changes from marketplace sales data to forecast driven data. It is the basis for supply chains moving towards continuous flow and away from point-to-point movements and ultimately to

![Figure 9](image-url)  
**Figure 9**  
The Reengineering Electronic Products Supply Chain

![Figure 10](image-url)  
**Figure 10**  
Estimated Improvements in Dynamic Performance of a Electronics Products Supply Chain at Various Stages of BPR Program
holistic control [37].

Management has attempted to address information flow difficulties by implementing Information Technology (IT) based solutions such as EDI. But IT driven solutions frequently fail to deliver the full potential benefits. So the question many managers are asking is why despite implementing IT have the traditional problems associated with information flow not been eradicated? The answer is that IT is not the unique solution because it is just one of many tools required. What is of crucial importance is the information usage methodology adopted when using IT. If the actual information transference strategy remains the same then the bolted-on IT will only succeed in moving distorted data faster! This is because the newly adopted IT is utilizing the existing information strategy and hence still contains the same decision points that led to the original upstream information distortion.

Significant dynamic performance benefits will accrue if the value of the information transferred with the supply chain is improved thereby reducing bias, noise, and staleness. There is evidence that this is now happening on a major scale [38]. The approach is to establish an information decoupling point and place it as far upstream as possible enabling as many members of the supply chain as possible to access the actual marketplace data. Businesses at each echelon can decide how best to exploit undistorted information in their delivery and planning processes. They usually have to overcome the functional silo mentality where information is regarded as power to the individual, and replace it with a philosophy that transparent information flow means more power and more profitability for the entire chain.

References


