Overlapping Product Development Activities By Analysis of Information Transfer Practice

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Abstract

Our research focuses on the problem of identifying improvements in the product development process that can help firms realize better products faster. In this paper, we describe a three step methodology to analyze the information transfer practice in a product development process. The methodology helps identify modifications in the information transfer practice which enables increased overlapping of development activities and reduced development lead time. The modifications identified pertain to (i) the timing of information transfers among product development functions (ii) the content and level of aggregation of information exchanged and (iii) the use of preliminary or advance information transfers. When applied to an automobile door design process at a US automaker, the methodology helps achieve a 40% reduction in design lead time.

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1. Introduction

Intense competition forces product development firms to develop new, higher quality products at an increasingly rapid pace. In our research, we focus on identifying improvements in the product development process that can help firms realize better products faster [5]. In an earlier work, we discussed the problem of ordering cross-functional design decision making to maximize quality [6]. In this paper, we describe an analytical methodology to overlap activities in order to expedite product delivery to the market.

By overlapping a product development process, we mean advancing downstream development activities to start before their information releasing upstream counterparts end, resulting in an overlap time period among the activities. Overlapped processes represent the spectrum between two processes of practical interest: sequential processes (in which the overlap period = 0) and the ideal concurrent processes (in which the overlap period equals duration of one of the activities). Figure 1 shows an overlapped process with two development activities, Design and Prototype. It is simple to show that the sum of development lead time (L) and overlap time (O) of the process equals the sum of activity durations. (L + O = D + P). So if durations D and P are constant, increasing the overlap time, O, reduces the development lead time, L. A study by Clark et. al[4] estimates that for a $10,000 car, each day saved in lead time represents, $1 million in profits.

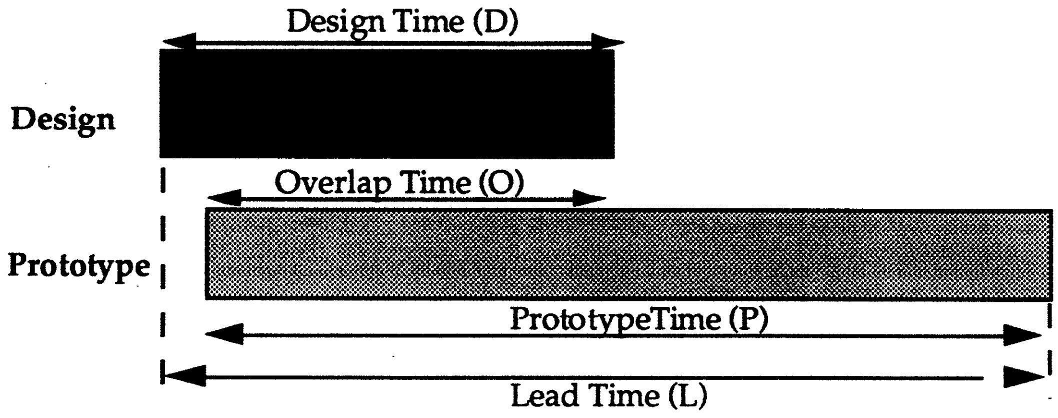

Figure 1: Overlapping Designing and Prototyping in Product Development

Overlapping product development functions however, could cause rework in the overlapped activities leading to an increase in the lead time. For instance, changes in design information in Figure 1, may require that the prototype be reworked or in the worst case, rebuilt. *The problem of increasing the overlap in an existing process, while achieving a lead time reduction is called the overlapping problem.* Our focus in this paper will be in developing an operational method to reduce lead time of an existing process by increasing overlap.

Many researchers have discussed the merits of overlapped processes[1, 3, 7]. Clark and Fujimoto [3] compare overlapped problem solving with the "phased" or sequential approach and argue that faster development processes are more overlapped. Whitney [7] discusses how Japanese development processes obtain time advantage by starting downstream activities with incomplete information. Blackburn [1] notes that overlapping activities shortens the lead time by stimulating parallel activities and by reducing time-consuming rework due to early detection of infeasibilities. To the best of our knowledge, no work has so far developed a methodology to increase the overlap in an existing process while achieving a lead time reduction.

2. The Arguments of this Paper

In this section, an automobile door design process is used to illustrate the main arguments of this paper:

1. The ability to overlap activities in a process is critically impacted by the prevailing (information) transfer practice. By transfer practice, we mean specifically, the timing, levels of aggregation and finality of the information transfers in the process.
2. Analysis of the information transfer practice, using the three step methodology presented in this paper, can identify modifications in the practice that help increase the overlap in the process and reduce lead time. As we show later in this paper, applying the methodology to an automobile door design process helps reduce door design lead time by about 40% (from 26 weeks to 16 weeks).

2.1 Information Transfer Practice Affects Overlapping

Consider the engineering design process of an automobile door, shown in Figure 2. Figure 3 displays the functional groups involved and the information exchanges among these groups in the existing design process[1] at our study company (a US automaker). The process of our focus starts with the release of the automobile theme information by the vehicle stylists and ends 26 weeks later with the release of die design information by the process designers. In the interim, there are multiple exchanges of product related information, notably wire frame, surface and draw information release by product designers, model release by model builders, updated surface release by engineering designers and updated model release by model builders. Figure 3 also gives the time in weeks at which the information exchanges happened in the existing design process.

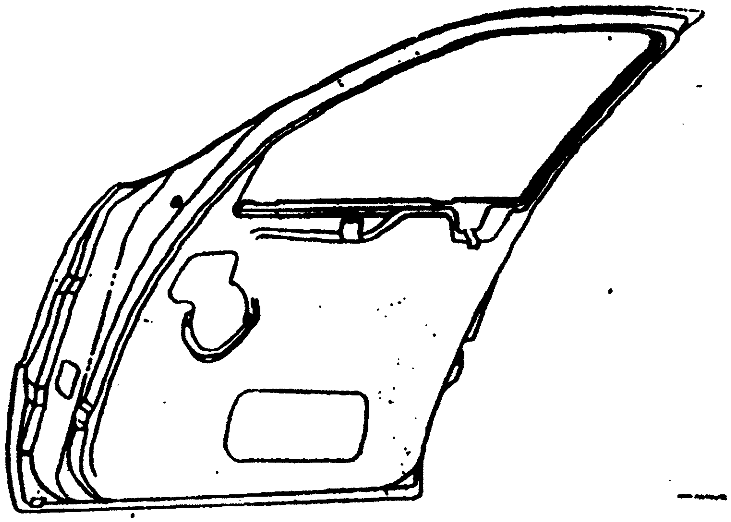

Figure 2: A Full Stamped Door in an Automobile

In the interest of overlapping a downstream activity such as die design, we ask, "why can't we overlap die design more?" Designing door panel dies requires the panel draw information from the panel designers; overlapping die design is *restricted* by the timing of transfer of panel draw information. An obvious approach to increase the overlap between die design and panel design is by advancing the draw information transfer time: by generating, transferring and utilizing draw information early. The degree to which overlap can be increased this way is however, limited by the extent to which timing of information transfer can be advanced (in the door case, the panel draw information cannot be advanced more

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[1] Our attention will be focused on the two major sheet metal parts of the door, inner and outer panel which involve the die design process, a time and cost driver.

than a certain amount of time because of the dependency of panel draw design on other transfers).

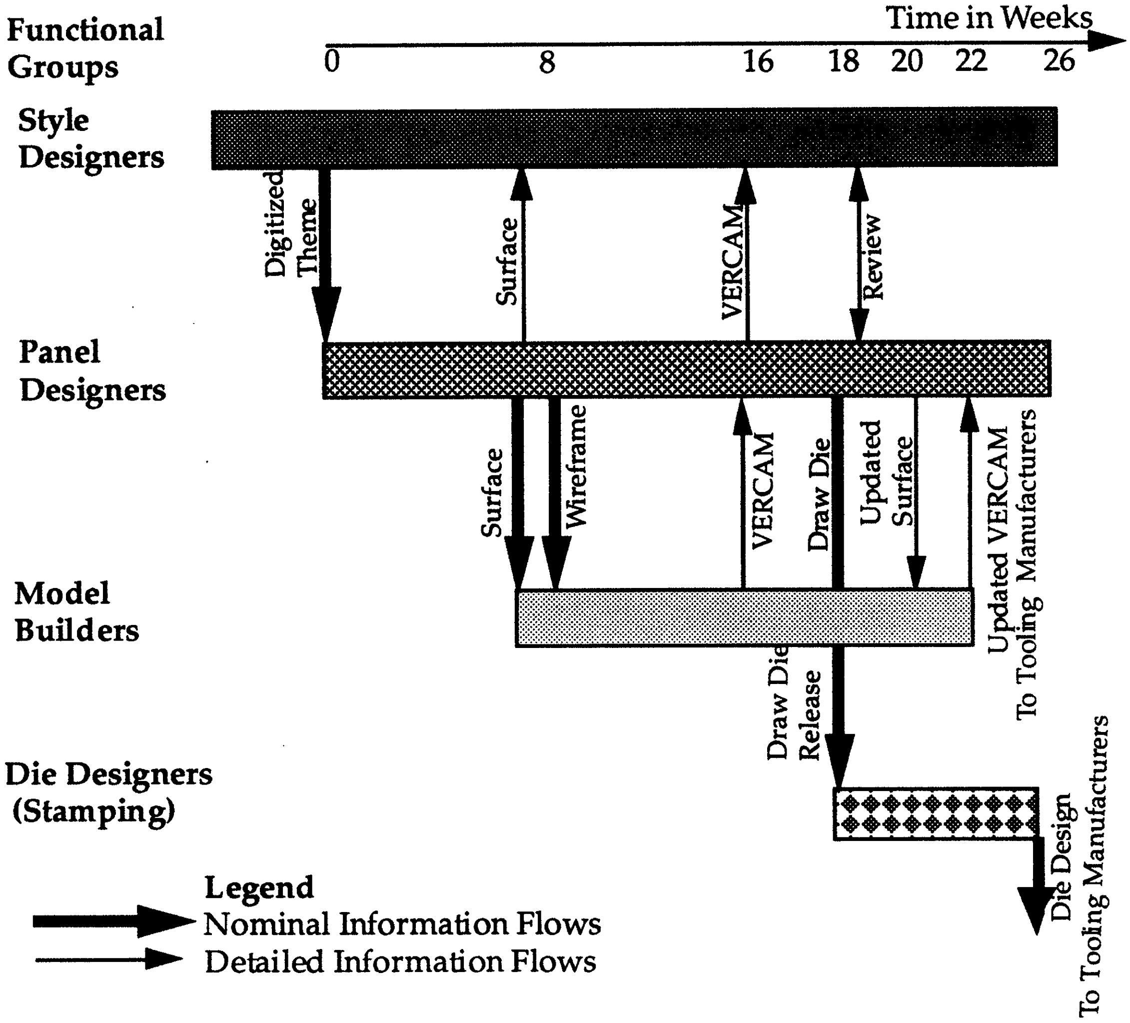

Figure 3: Information Transfers and Timings at our Study Company

Although the entire panel draw information cannot be determined any earlier, portions of it, such as the panel periphery draw information, can be ascertained far earlier. By transferring this information to the die designers upon generation, periphery die design (the difficult part of die design) can be "kicked-off" and the time overlap between panel design and die design can be increased. Note that a redefinition of the aggregation of the panel draw information into panel periphery and interior draw information has contributed to this increase in overlap. In other words, the level of aggregation of the information transfer impacts the ability to overlap a process (Clark and Fujimoto [3] arrive at a similar conclusion, while referring to aggregation as "batch size").

This approach of decreasing the aggregation of transferred information is also limited in its utility; it is not helpful when parts of the transferred information, such as the panel interior draw information, evolve very slowly (due to factors discussed later in the paper). In such situations, it is useful to consider transfer of unfinalized, advance information from upstream to downstream. If the penalty associated with changes in exchanged information are not severe, then it may be useful to transfer unfinalized design information (such as panel interior draw) and expedite the beginning of the downstream activity (panel interior die design). Note that the level of finality of information transfer affects overlapping: by transferring unfinalized information it possible to start downstream activities early and thereby increase the overlap among activities in the process. Transferring unfinalized information may result in rework in the downstream activity and needs to be carefully analyzed.

The above example illustrates that the timing, aggregation and finality of the information transfers impact the ability to overlap activities in a process. To overlap a process more, modifications need to be made in the transfer practice. How should the timing, aggregation and finality of the information transfers in an existing process be modified to facilitate better overlapping? The answer is obtained by performing what we call, (Information) Transfer Practice Analysis.

2.2 Transfer Practice Analysis Helps Increase Overlap

In the door panel die design situation, we observed that advancing the timing and reducing the aggregation and finality of draw information transfer helps increase overlap of die design with panel design. Is it possible to advance the timing of an information transfer in a process and if yes, by how much? If the timing of a particular information transfer cannot be advanced, is it useful to change the aggregation or finality of the information transferred? How much uncertainty is tolerable when transferring information from upstream to downstream? We attempt to answer these questions using (Information) Transfer Practice Analysis.

Transfer Practice Analysis comprises of three steps. Central to the first step (Section 3), is the decomposition of the existing process at (information) *transfer points,* which are points of information exchange among functions we wish to overlap. Because we are modeling the existing process, we assume in this step that the level of aggregation and finality of each transfer point in the model is the same as that of the existing process. (The number of transfer points in the model equals the number of information exchanges in the process). The constraint between transfer points i and j corresponds to the minimum time required to transform[2] the information in point j into the information in point i. The constraints, called *transfer constraints,* will be represented in a matrix form and processed (using algebra similar to critical path method [2, 9]) to determine which transfers are coupled, which ones are delayed in the existing process and which ones affect lead time.

In the second step of analysis (Section 4), we examine the impact of the level of aggregation of information transfers on overlapping. Change in aggregation is accomplished by increasing the number of transfer points, which results in a modification in the transfer constraints. We analyze the transfer constraints to see if overlap can be increased and lead time can be reduced. We also present specific heuristics to aid in redefining the level of aggregation of transfer points.

In the third step of transfer practice analysis, we consider situations where information needs to be transferred in an advance or unfinalized form to overlap activities(Section 5). We model both the evolution rate of transferred information and its influence on the downstream activity to determine the *optimal* timing and finality of information transfer that minimizes lead time by increasing overlap.

3. Transfer Timing Analysis

In this section, we decompose the existing process at points of information transfers among the different design functions. The number, aggregation and finality of the transfer points are assumed in this section to be the same as the modeled process. Because our analysis in this section relates to the timing of transfers, we call this step, Transfer Timing Analysis.

Consider the information transfers in the door design process as shown in Figure 3. It is noteworthy that these transfers are separated in time by several weeks, the time

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[2] This model is based on our view of product development process as *a complex process of transformation and transmission of product-related information* [8].

required to transform product information into a more detailed design or a physical model and transmit it downstream. For example, to transform vehicle theme information into a wire frame (edge-based) model, panel designers require four weeks: to (i) Decide the door-body interface ("P1, P2" lines) (ii) Develop the details of boundaries and other feature lines (iii) Develop typical sections and (iv) Verify and release information. (Each activity takes a week). We refer to the constraint, that wire frame cannot be released earlier than 4 weeks after theme release, as transfer constraint. We studied the door design process in detail to obtain all other transfer constraints, which are summarized in Figure 4 in a matrix called the Transfer Constraints Matrix (TCM). TCM(i, j) represents the time required to transform the information in transfer point j into the information in transfer point i.

		1	2	3	4	5	6	7	8
Theme Transfer	1	0							
Wire frame Transfer	2	4	0						
Surface Transfer	3	7		0					
VERCAM I Transfer	4	10	7	4	0				
Modified Surface Transfer	5				2	0			
VERCAM II Transfer	6					2	0		
Draw Die Transfer	7	18						0	
Die Design Transfer	8							8	0

Figure 4: Transfer Constraints Matrix

The TCM in Figure 4 was filled in the following manner[3]:

- As discussed earlier TCM(2, 1) , which is the minimum time required to release wire frame information after the theme is released by the stylists, equals 4 weeks.
- To develop the surface, engineers use the P1 and P2 lines and other feature lines and sections developed earlier. Developing a mathematically correct surface involves (i) Developing the Main Surface of the panel (1 week) (ii) Developing the

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[3] The diagonal elements are all zero, as they represent the time separation of a transfer point from itself. Also, we include only the minimum time separation constraints among the transfer points, with the result of which the TCM is lower triangular. There are situations in which there could be an upper limit on the time difference between two transfer points, which can be shown to be an above diagonal term of the TCM. We discuss this aspect elsewhere.

Trim Surface (1 week) and (iii) Reviewing the developed surface with designers (1 week). The developed surface can be released a week later after checking and adding the correct formats (seven weeks after the theme release).

- A draw die release currently contains details of all surface formations both on the outer periphery and the inside of the panels. Releasing inner panel draw die information takes a long time, because the designers wait to establish the final positions of all formations by negotiating with electrical systems group (speakers, wiring locations), and the door hardware group (regarding window regulators and connection path to the door locks). The outer panel draw die release waits for information about the door handle profile and depth. Currently, the draw die information, as defined, cannot be released until 18 weeks after theme release.
- Die design uses the draw die information released by product designers. Stamping engineers design the dies for the periphery (draw, trim and flange die) in 4 weeks and the dies for the panel interior (pierce and draw dies) in another 4 weeks. Die design information is ready for release 8 weeks after the draw die release.
- VERCAMs are verification models built by vendors to verify the surface developed by panel designers. VERCAMs are cut out of a special material called Renplank over a honeycomb base. The vendors needed to build a VERCAM can be identified 3 weeks after the theme release. The selected vendors "block" their models to the wire frame release (4 weeks). Finally, the vendors use the surface information to code and cut their models (3 weeks). A VERCAM cannot be released earlier than 10 weeks after theme release, 7 weeks after wire frame release and 3 weeks after surface release.
- The first iteration of VERCAM, cut by vendors, is reviewed by stylists and product designers. Often changes need to be made and the modified surface is submitted to the vendors for a second VERCAM. The second VERCAM is available 2 weeks after the modified surface release.

It is clear from the above that, although it is theoretically possible to release VERCAM I 10 weeks after theme release, it cannot actually be released 11 weeks after theme release because, the surface information can be released earliest at the seventh week (it takes at least 4 weeks from surface release to VERCAM I release). We compute the earliest times at which the various product-information can be released and display it in Figure 5 as the Transfer Timing Matrix (we are essentially identifying the longest time distance between any two transfer points; this paper is devoted to the discussion of the transfer practice analysis, so we will not describe the mathematical details of determining the transfer timing which is similar to the critical path method). The Transfer Timing Matrix (TTM) shows that the VERCAM II information can be released the 15th week, seven weeks ahead of the release in the existing process (22nd week; see Figure 3). In the existing process, VERCAM development does not start with the theme release; the model builders who build VERCAM are brought in only at the surface release stage. Also, there is a delay in transmitting the wire frame and surface information to the downstream processes.

The delay in transmitting wire frame and surface information does not however, affect the lead time of the process because the die design information transfer dictates process lead time. The rearranged TTM in Figure 6 shows that the die design transfer is unaffected by the VERCAM transfer. Also, the draw information in the existing process is indeed transferred at the earliest possible time (18th week), without any transmission delay. So it is not possible to reduce lead time of the process in Figure 3 by reducing delay in transmission of wire frame and surface information.

		1	2	3	4	5	6	7	8
Theme Transfer	1	0							
Wire frame Transfer	2	4	0						
Surface Transfer	3	7		0					
VERCAM I Transfer	4	11	7	4	0				
Modified Surface Transfer	5	13	9	6	2	0			
VERCAM II Transfer	6	15	11	8	4	2	0		
Draw Die Transfer	7	18						0	
Die Design Transfer	8	26						8	0

Figure 5: Transfer Timing Matrix

3.1 Discussion

Transfer Timing Analysis decomposes the prevailing process in a unique fashion, into transfer points and considers the constraints among the transfer points to determine which information transfers (i) are coupled (ii) have a transmission delay in the existing process and (iii) determine the lead time. The transfer point decomposition is efficient because it models the process just at the right level of detail required to make the interfaces transparent. Although the transfer point based decomposition has an equivalent activity based representation, it is one among the many possible activity based decompositions of the process. So doing a conventional activity based decomposition may not (and has been seen in practice to not) lead to the same decomposition as the transfer point representation. Our experience with a project management model of the door design process shows that the activity based decomposition could result in too much detail in some parts of the process and too little detail in some other parts to identify opportunities to overlap the process.

		1	2	3	4	5	6	1	7	8
Theme Transfer	1	0								
Wire frame Transfer	2	4	0							
Surface Transfer	3	7		0						
VERCAM I Transfer	4	11	7	4	0					
Modified Surface Transfer	5	13	9	6	2	0				
VERCAM II Transfer	6	15	11	8	4	2	0			
Theme Transfer	1							0		
Draw Die Transfer	7							18	0	
Die Design Transfer	8							26	8	0

Figure 6: Rearranged Transfer Timing Matrix

Reducing transmission delays helps increase overlap among upstream and downstream activities and can help detect infeasibilities early. However, reducing delays in only those transfers that affect the lead time, helps reduce lead time. Often development processes of competitive products are streamlined enough to ensure that there are no delays in transfers that affect lead time. In such cases, after examining the timing of transfers it is important to analyze other aspects of the transfer practice, such as the level of aggregation and finality of the information transfers.

4. Aggregation of Transfer Points

Consider once again, the door development process. We noted that the die design transfer determines the lead time and occurs without any delay: there is no difference between the time predicted by the TTM and the actual process for the draw information and the die design information transfers (see Figure 7).

Theme Transfer	1	0		
Draw Die Transfer	7	18	0	
Die Design Transfer	8	26	8	0

Figure 7: Door Panel Die Information Transfer Timings

Notice that the draw die information cannot be transferred until 18 weeks. As discussed earlier, the panel periphery draw details can be ascertained earlier. Will the transfer of periphery draw information reduce the lead time of the process? The answer depends on the way the transfer constraints are affected by such a transfer. We reduce the level of aggregation by increasing the number of transfer points in the die design information transfer path (increase the rows and columns of the matrix as in Figure 8) and rewrite the transfer constraints.

		1	7a	7b	8
Theme Transfer	1	0			
Periphery Draw Die Transfer	7a	7	0		
Interior Draw Die Transfer	7b	18		0	
Die Design Transfer	8		8	4	0

Figure 8: Transfer Constraints while Increasing Transfer Points

Theme Transfer	1	0			
Periphery Draw Die Transfer	7a	7	0		
Interior Draw Die Transfer	7b	18		0	
Die Design Transfer	8	22	8	4	0

Figure 9: Transfer Timings for the Modified Transfer Process

Computation of the transfer timings from the constraints given in Figure 8 shows that the die design transfer time - and thereby the process lead time- can be reduced by four weeks (see Figure 9). Notice that the transfer of periphery draw information promotes the periphery die design activity and if the interior draw information were available at the 11th week, die design information will be available the 15th week. But interior draw information is not ready until the 18th week (because of packaging and door handle decision making) and so die design information will not be available until the 22nd week after theme release.

4.1 Heuristics for Increasing Number of Transfer Points

From the draw information transfer example, we observe that reducing the aggregation of information transfers by increasing the number of transfer points helps overlap activities more and reduce lead time. Several questions arise: Does this always work? If not, when does it work and why?

In the door panel die development, we found that there was a huge time lag between the theme release and the draw die release. Parts of the information contained in the draw die release have the following characteristics: (a) they are available for transfer at an earlier time and (b) they can be of use to the downstream functions, such as die design. Increasing the number of transfer points is a strategy worth attempting whenever we have a critical transfer path with huge timing differences among the transfer points. It is effective when the newly introduced transfer points alter the transfer constraints so as to reduce the timing distances among the erstwhile transfer points.

From an engineering standpoint, increasing the transfer points should be based on (i) an understanding of what upstream information is of use to the downstream process and (ii) which parts of upstream information transfer are available early. In the door case, it turned out that the periphery draw information will be of use to the die designers. If parts of the transferred information are not of use to the downstream functions, such as parts of a VERCAM model or parts of the interior draw information, then reducing the aggregation of transfers is not of much value.

5. Transferring Unfinalized Information

In the previous sections, we considered both the timing and aggregation of information transfers. Analysis of timing helps reduce transmission delays; analysis of aggregation helps increase the frequency of transfers and thereby start downstream functions. The information exchanged is still certain or frozen information, the advantage being the information is transferred as soon as it is generated and utilized as soon as it is received.

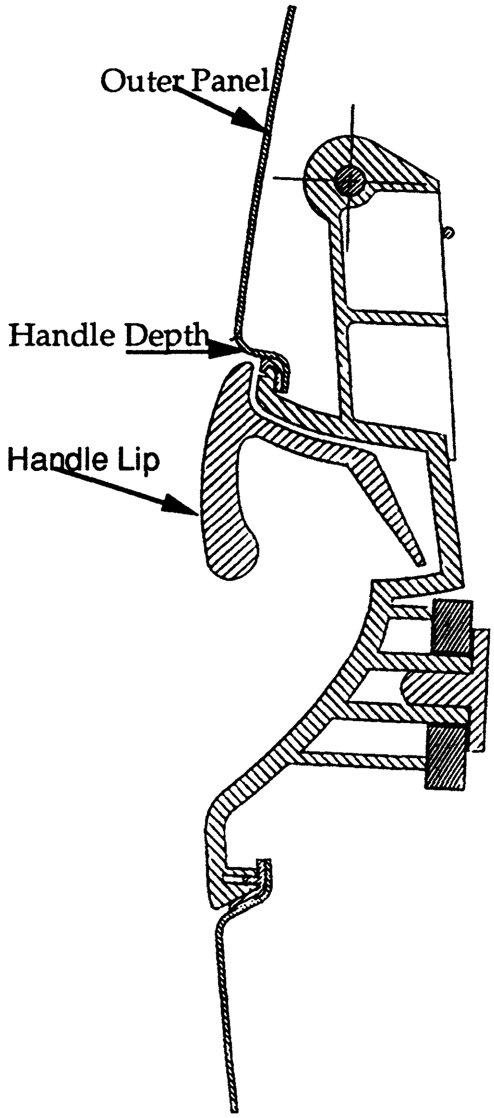


Figure 10: Door Handle Depth in the Outer Panel

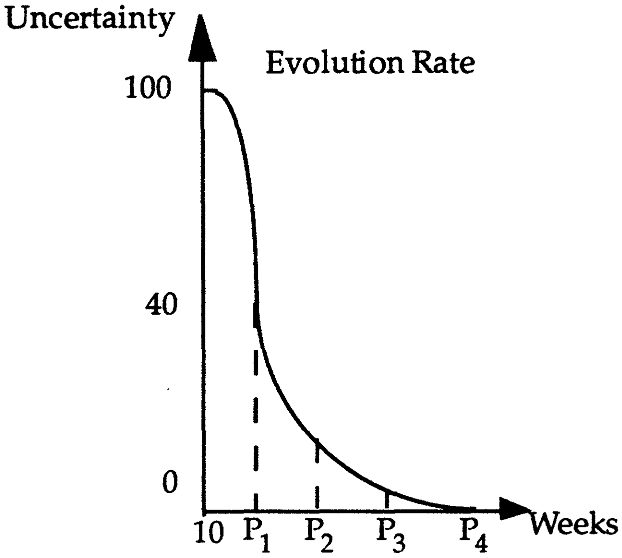
Consider the case of interior draw information transfer. As we observed earlier, there are no transmission delays. The reason why the transfer takes so much time is that the required piece of information evolves very slowly. The reason for the slow evolution are different for the outer and inner panel interiors. The inner panel interior draw determination requires the configuration of various formations, which requires substantial cross functional negotiation. The outer panel interior draw information transfer on the other hand, is delayed by the time taken to decide the door handle parameters: profile and depth. In this section, we will use the door handle as an example of a case where transferring advance information is useful in overlapping functions.

We first consider the evolution of door handle design decision. Stylists and Designers want to make the decision about the door handle profile and other parameters as close to the launch as possible, both to differentiate the handle from recent competitor products and to suit current customer preferences. The door handle depth into the outer panel information (Figure 10) is however used in the die design activity and the later this decision is made, the more the start of die form design will be delayed (causing perhaps, an increase in overall lead time). How do we satisfy both the concerns: product differentiation and lead time minimization?

If preliminary information were exchanged, if die designers were to start with unfrozen door handle depths, then both the concerns can be met. However, this depends on how sensitive die design is to the door handle depth information and at what rate the certainty of door handle design information improves; If die design is rather insensitive to the door handle depth within limits, as is the case in practice, then it makes practical sense to start die design with advance information about the depth and later process the change in door handle depth. This will not be the case if the door handle depth has a large influence on the die design activity, because processing the change in the depth may increase die design duration considerably and thereby cause lead times to slip. Starting downstream activity early, with advance information, helps in increasing the overlap with upstream activity but may also increase the downstream duration. In this section, we will develop a simple model of this situation by formalizing the notions of "influence" of exchanged information on the downstream activity, rate of change of "uncertainty" of exchanged information etc., towards determining the *optimal transfer policy* (the timing of information transfer that minimizes the lead time).

5.1 A Simple Model

We consider the case of a transfer of a single piece of information, x. The certainty with which x, is known changes with the time. This change is captured by the Uncertainty Function, in Figure 11. (When we say x is uncertain, we mean that the confidence interval (CI) in which the value of x lies is of non zero width. Larger the width of this CI, greater is said to be the uncertainty. At zero uncertainty, the width of the confidence interval is zero, the value of x is known as a point. Thus, uncertainty is assumed to be proportional to the width of the CI) . In the door handle case, the uncertainty in the door handle depth decreases as more input is available. This change can be based on the intermediate activities that designers perform to confirm the depth: consultation with styling, finite element analysis, cost calculations, vendor feed back, stamping feed back etc. In other words we have an Activity based Uncertainty Function.



For the Door Handle Example:

P_1 : Styling Input on Handle Pocket Profile (12th week; 40% uncertainty)

P_2 : Finite Element Analysis (14th week;25% uncertainty)

P_3 : Vendor Feed back Available (16th week; 15% uncertainty)

P_4 : Stamping Feedback in (18th week; 2% uncertainty)

Figure 11: Uncertainty Function

(Note that for the door handle, until 10 weeks from theme release, there is no concept and so no confidence interval for the depth. A CI exists only after the concept is finalized).

A change in the value of transferred information, *x*, causes an increase in downstream duration required to process the change. This change will be determined by the nature of the downstream activity and is captured by the Influence *Function* . In the door example depicted in Figure 12, any change causes a small increase in the downstream duration, 1 day, required to update drawings, fill engineering change orders and get approvals. However, if the changes in the value of depth are beyond 2 mm, the feasible domain beyond which die could tear off, then the whole draw die needs to be redesigned.

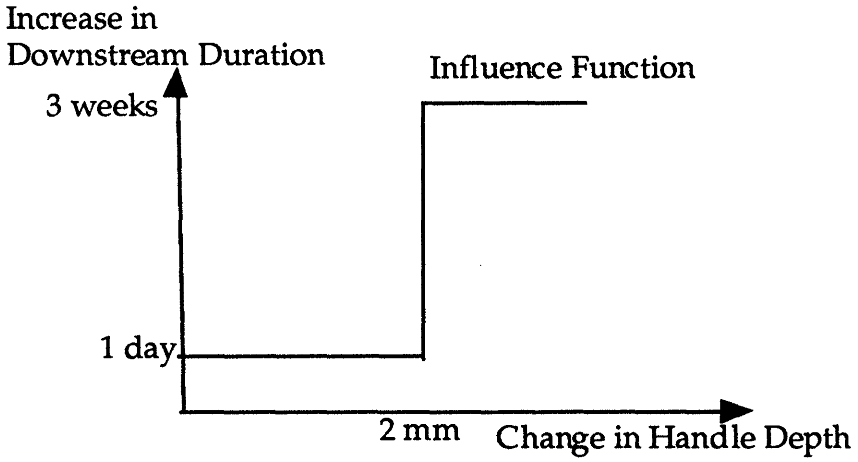


Figure 12: Example of Influence Function relating the change in the downstream duration to the change in exchanged information.

The change in the value of x between times t_1 and t_2 is calculated as follows. Suppose the uncertainty associated with x at time t_1 is UC_1 and at time t_2 is UC_2, then the expected change(EC) in x between times t_1 and t_2, $EC(x; t_1, t_2)$, is given by:

$$EC(x; t_1 , t_2) = CC^* (UC_1 - UC_2)$$

where CC is the Change Coefficient to be defined below. This can be explained as follows. We mentioned earlier that uncertainty is assumed to be proportional to the width of the confidence interval. Suppose at time t_1 when the uncertainty is UC_1, the confidence interval is $\{a_1, b_1\}$ and at time t_2, when the uncertainty is UC_2, the CI is $\{a_2, b_2\}$. Due to the proportionality of the uncertainty and the width of the CI, we have:

$(b_1 - a_1) = k^*UC_1$; $(b_2 - a_2) = k^* UC_2 \Rightarrow (b_2 - a_2) = (UC_2/UC_1)^*(b_1 - a_1)$.

Suppose also that downstream requires a point estimate of x from upstream and assuming a uniform distribution in the CI, the estimate that will be provided by the upstream activity at t_1 will equal the expected value, $(a_1 + b_1)/2$. Similarly at time t_2, the estimate will be $(a_2 + b_2)/2$. We want to find the value of a_2 and b_2 that maximizes the change in the estimate, $(a_2 + b_2)/2 - (a_1 + b_1)/2$. *To do so, we assume that uncertainty decreases monotonically with time* : if $t_2 \geq t_1$, then $\{a_2, b_2\}$ is a subset of $\{a_1, b_1\}$; In other words, for $t_2 \geq t_1$, $b_2 \leq b_1$ and $a_2 \geq a_1$.

Now we have a simple mathematical optimization problem:

$\mathrm{Max}\{(a_2 + b_2)/2 - (a_1 + b_1)/2\}$subject to:

$b_2 - a_2 = (UC_2/UC_1)^*(b_1 - a_1)$; $b_2 \leq b_1$; $a_2 \geq a_1$;

Using the fact that $(b_1 - a_1) = k^*UC_1$; $(b_2 - a_2) = k^* UC_2$, we have the solution for the problem:

$b_2 = b_1$
$a_2 = b_1 - k^* UC_2$
Change in estimate = $k/2\ (UC_1 - UC_2)$;
How do we determine the value of k? If we substitute $UC_1 = 1$ and $UC_2 = 0$, (i. e, we consider the two extremes, 100% uncertainty and 0% uncertainty) Change in estimate = $k/2$. We will call this the Change Coefficient (CC). If at 100% uncertainty, the CI = $\{a_{in}, b_{in}\}$, then the estimate is $(a_{in} + b_{in})/2$; at 0% uncertainty the CI is of zero width and within $\{a_{in}, b_{in}\}$. The maximum expected change in estimate from 100% to 0% uncertainty = $(a_{in} + b_{in})/2$. So **CC = $(a_{in} + b_{in})/2$.**

Let us reiterate the *assumptions* in deriving $EC(x; t_1, t_2) = CC^* (UC_1 - UC_2)$

- Uncertainty decreases monotonically with time: If $t_2 \geq t_1$, $UC_2 \leq UC_1$.
- Downstream requires a point estimate of x from upstream activity
- The probability distribution within CI is a mean centered distribution.

5.2 The Optimal Transfer Policy

We want to determine the optimal transfer policy, the time at which the information transfer should occur to minimize the lead time. For the door handle case we take the initial confidence interval $\{a_{in}, b_{in}\}$ as equal to {2, 8} mm. Figure 13 shows the lead time Vs timing of transfer for the door handle. The minimum lead time of 16 weeks is attained by transfer of advance door handle information at the 12th week after theme release.

Figure 13 confirms our intuition that it is not advisable to transfer handle information before styling input is in; once styling decides the profile and depth, these parameters do not change much and so handle information can be transferred downstream. Waiting until the door handle decision is completely frozen gives us a lead time of 22 weeks, which is what we got in Section 4 (Figure 9). The solution is sensitive to the confidence intervals we choose; so it is probably more robust to transfer the door handle information a little beyond the optimal point. Note that this is a classic example of situations where overlapping is not always productive; overlapping beyond 12 weeks increases the lead time. The reason why the lead time falls so suddenly is due to the discontinuous form of the influence function (at 12 weeks, the confidence about door handle decision is so high any change after 12 weeks will fall within 2 mm preventing redesign). Also, this analysis is valid only after the handle concept is chosen (10 weeks after theme release).

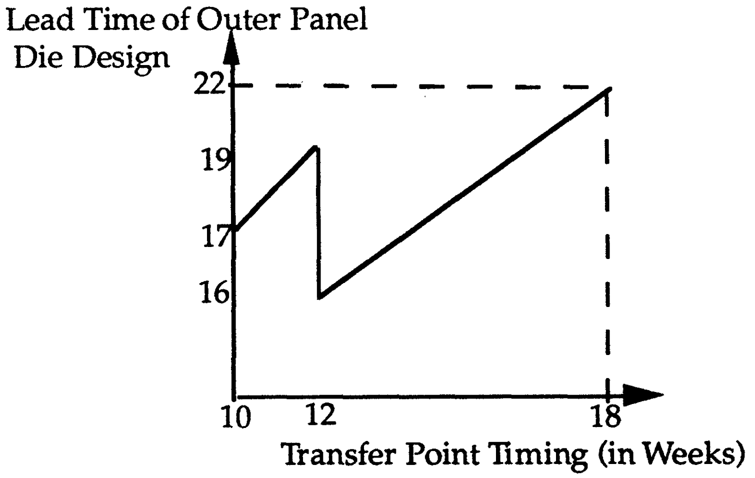


Figure 13: Lead Time Vs Handle Information Transfer Timing

6. Summary

In this section, we first itemize our recommendations to the study company based on Transfer Practice Analysis and then summarize the analysis methodology.

6.1 Recommendations to Study Company

The lead time of the door development process can be decreased by the following:

- Freeze periphery draw decisions early and transfer them downstream. This will help kickoff the design of draw, trim and flange dies for the panel periphery.
- Transfer door handle design information to stamping early, as soon as styling decision is known. Keep stamping posted with any changes in handle design.
- If VERCAM is developed to verify surface, start VERCAM development with the theme release. Vendors can be identified upon theme release; Wire frame release can be used to block the VERCAM. Surface release can then be used to code and cut the VERCAM.

These recommendations will help reduce door outer panel development time from 26 weeks to 16 weeks (40% reduction).

6.2 Transfer Practice Analysis Methodology

The analysis methodology we used in this paper consists of the following steps:

0. Identify functions to overlap and current information transfers among them.
1. Model existing info. transfer practice in terms of transfer points.
    a) Number of transfer points = number of information transfers.
    b) Obtain constraints among transfer points by studying the process.
    c) Resolve constraints; Compare with existing process for delays.
    d) Obtain critical transfer path that determines lead time.
2. Change content of information transfers in critical transfer path.
    a) Split transfer points; update transfer constraints & critical path.
    b) Examine neighboring points which are affected by the split points.
3. Analyze finality of information transfers.
    a) Model evolution and downstream influence of exchanged info.
    b) Determine point of transfer that minimizes lead time.
4. Make recommendations for a new Transfer Policy based on modification identified by analysis

The Transfer Practice Analysis methodology has been quite useful in modeling and analyzing the door design process. The models used are however, simple, first-cut, approximate models especially, in the modeling of information evolution and influence on downstream functions. Our future work has two parts:

- Apply the methodology to the development of other engineering products to gather more insights about modeling information aggregation and evolution.
- Develop and test applicability of more detailed models of the process of exchange of preliminary design information among development functions.

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