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# LOGISTIC PROFILE: A NEW CONCEPT FOR INTERFACING DESIGNERS AND LOGISTICIANS IN CONCURRENT ENGINEERING ENVIRONMENT

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## Abstract

The distribution of industrial activities in a global basis, as well as the increasing search for delivery time reduction have demanded effective integration of logistical issues into product design decision-making. However, current engineering design organizations and tools are not suited for structuring proper interface between engineering and logistics. In this paper, we propose the Logistic Profile, a conceptual tool for supporting interface between designers and logisticians who take part in cross-functional teams of concurrent engineering environments. This work is based on results of an empirical research developed at a heavy-equipment manufacturer sited in France.

*Keywords: Logistic Profile, Design, Interface, Logistics, Concurrent Engineering.*

## 1. Introduction

Product-process integration and project activities overlapping are well known engineering approaches for reducing time-to-market of new products, as well as total development costs. In order to achieve these competencies, different industries have deployed New Product Development process (NPD) and Concurrent Engineering as project management and organizational models respectively [1].

Nevertheless, distributed procurement, supply, and manufacturing have extended the challenge of time-to-market reduction to issues concerning final product delivery time, which spans engineering design borders [2]. As a consequence, logistical problems related to multi-facility supplier selection and management, procurement, long supply time, inventory and transportation costs are becoming recurring in engineering design decision-making. In such scenario, logisticians effective integration all along product development process is becoming mandatory.

The problem is that many NPD and Concurrent Engineering approaches assume that logistics issues are already embedded into product-process integration problem and solution [3, 4]. Clear evidence is that current approaches and integration tools are mostly specific and process-oriented (*e.g.* assembly, machining, forging, welding and so forth), not paying attention to logistics specificities. Thus, logisticians who usually take part in cross-functional teams of concurrent engineering environments do not have until now suited tools to interface early into product-process design activities.

It follows that logistics issues take place late on the development process, still pursuing a traditional sequential approach supported by well-structured information at the interface with design engineers, like procurement bill-of-materials. Risks of such approach are product time-to-market delays due to procurement and supply lead-times, unexpected burden costs of late changes on product and tooling designs, complex handling of new product components, long production and delivery lead-times, as well as high logistics costs in inventory and transportation during maturity stage of product life-cycle.

In this paper, we present and develop the Logistic Profile concept for structuring proper interface between design engineers and logisticians all along NPD projects in a Concurrent Engineering organization. We consider logisticians as functional team members with skills in product configuration management, procurement, supply and support for final assembly process. Furthermore, we prescribe how they should interface with design engineers centered on Logistic Profile development and use. Such concept results of our findings during an empirical research executed at a heavy-equipment manufacturer.

## 2. Tools and approaches for integrating logistics issues into product design

Design For Logistics (DFL) has been described in literature as an effective tool for taking into account logistics in product design early phases [5, 6, 7]. DFL approach follows the rationale of Design For X (DFX) and it proposes generalizing design prescriptions for designers aiming cost reduction through minimization of part reference number, tailored packaging or easier handling [8].

For example, Mather suggested that designers should integrate DFL as a support for designing logistically-effective products [5]. Dowlatshahi's DFL model aims to integrate logistics related issues by defining general prescriptions concerning four design-logistics interfaces: Logistics Engineering, Manufacturing Logistics, Design for Packaging, and Design for Transportability [6]. Taking designer's standpoint, these works provide a theoretical basis for thinking logistics integration problem, but some questions remains: How logisticians could co-operate in concurrent design efforts or still how designers and logisticians should interact in practice? Is it possible to translate a design solution in terms of logistic parameters? How to consider specificities of each logistics organization beyond design general prescriptions?

Our approach is based on structuring proper interfacing between logisticians and design engineers. We believe that well-structured interfacing allows effective participation of logisticians all along design process, supporting engineering-logistics trade-offs and overcoming barriers and late conflicts between them in the design project. In effect, the word *interface* is related to links, interactions, and collaboration between two or more organizations, industrial functions, or team-members and the importance of suitable interfacing for supporting concurrent design activity has already been stressed in literature [9, 10, 11]. For example, Boujut and Blanco claim that collaborative work is "a typical situation where interfaces are of prime importance" [12].

In this paper, we consider an interface as a work structure that comprises a set of fundamental elements (specifically, interface members, artifacts and objects, tools, procedures and rules, spaces and time for interfacing) to support and to rationalize interactions between members of a concurrent design team during design activity [13]. Interactions may be expressed in terms of mutual learning, knowledge creation, negotiations of tradeoffs about conflicting standpoints, and communication in a broad sense. Particularly, we are interested on tools as a crucial interface element in order to assist designers and logisticians in their co-operative work along concurrent engineering activities.

## 3. A development project of a new family of construction equipments

In order to study logistics involvement in product design, we took part for two years in a New Product Development project (NPD) of a new family of construction machines (dozing, earthmoving, grading, etc.) developed by a heavy-equipment manufacturer sited in France, which designs and produces different categories of track loaders, track tractors and other machineries.

NPD process follows classical stage-gate approach, where activities are laid out in phases (concept generation, detailed specification, preliminary design, detailed design, production introduction, volume production) and each phase comprises design and gate reviews [1, 14]. Project management and execution are centered in France, but most of machine's system design requires participation of first-tier suppliers distributed worldwide. CAD modeling and Product Data Management are main design tools and teams also use CAE simulation and Virtual Assembly as product-process integration tools.

Concurrent engineering is organized in cross-functional teams, which are responsible for a specific system of the machine (engine, hydraulics, powertrain, operator cab, among others). Each team has a leader engineer and design engineers, as well as other permanent members from Marketing, Purchasing, Manufacturing (machining, cutting, welding, assembly), and Logistics. Other industrial functions integrate teams when required, as resource members.

In this company, logistics plays an important role because main raw material and components (sub-systems, sub-assemblies and parts) are procured and supplied on a global basis according to different strategies for supplying final assembly in France. Logistics function integrates different services that are responsible for upstream supply chain management (for example production planning, procurement, inventory, supply, and transportation), as well as operations related to internal logistics for supporting production and for final products expedition.

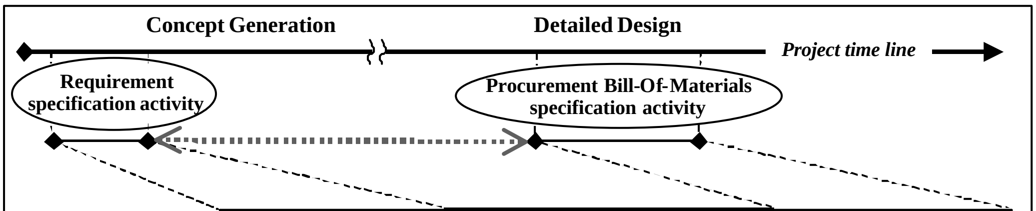
The NPD project we have followed has specificities that are particularly challenging from design and logistics point of views. First, the time-to-market and product delivery time targets should be considerably reduced in comparison with current machines, which demand specific coordination and strong co-operation between engineering and logistics from the very beginning. Second, the project aims modular assembly, which requires changing well-established paradigms in design approach and organization, mainly concerning product architecture (from functional systems to multi-functional modules). Third, modules are to be supplied by few first-tier suppliers that require innovating logistical solutions in terms of information and physical flows.

We have employed an empirical approach based on Action Research methodology for our studies [15, 16]. In a first stage, we were directly involved in NPD activities, attending regular meetings and gate reviews, which allowed us to analyze engineering-logistics interfacing shortcomings according to a three dimensional approach: organizational, chronological and instrumental [17].

In terms of interfacing, we have observed that two activities, formally established in the design process, represent two periods of interaction between engineering and logistics: requirement specification and procurement bill-of-materials specification (figure 1).

During the first period, before conceptual generation phase, engineering asks for each industrial function (purchasing, manufacturing, logistics, etc.) to identify and specify theirs strategic requirements in respect to the NPD project. QFD tool (Quality Function Deployment - *Voice Of Business matrix*) is used for supporting this activity, as well as customer needs identification (*Voice Of Customer matrix*). Both matrixes are inputs for defining product and process functional requirements.

Problem is that logistics requirements should also be translated in terms of design metrics to appropriately be integrated into product requirements, but neither logisticians have a specific tool for such a translation nor designers know sufficiently how logistics processes work for developing design rules for taking into account logistics issues in a prescriptive manner. Due to the lack of suitable support, the result of this first period is a weak engineering-logistics interfacing, characterized by sparse interactions during *Voice Of Business matrix* construction.




| | PERIOD OF WEAK INTERFACING | PERIOD OF NO INTERFACING | PERIOD OF STRONG INTERFACING |
|---|---|---|---|
| Product structure level | *Machine's family level* | *Architecture, systems, sub-systems, module, part levels* | *Reference level* |
| Engineering Design tools | *QFD "Voice Of Customer" / "Voice Of Business"* | *FMEA; CAD; FEA; PDM; Virtual Assembly; Nomenclature Management.* | *CAD; PDM; Nomenclature Management* |
| Logistics tools | - | - | *Bill-Of-Material releasing tool; Logistics Data Systems* |
| Design-Logistics Interface tools | - | - | *Proprietary tools and specific procedures* |
| Main Project Deliverables | *Product-process functional requirements* | *Product-process concept; technical specs.; design solutions; 3-D CAD models; drawings.* | *Consolidated Product Nomenclatures and Procurement bill-of-materials* |

Figure 1. Periods of weak and strong interfacing between designers and logisticians during project activities. The periods of weak and no interfacing are characterized by a lack of design-logistics interface tools.

At the end of detailed design phase, the second period of interactions is characterized by strong interfacing between engineering and logistics (figure 1). The most important activity is the specification of procurement bill-of-materials from product nomenclatures developed by engineering. This billing contains all parameters required by logistics for formalizing and structuring all information concerning procurement, supply and maintenance of each single reference of the product nomenclature. As logistics and engineering are stakeholders of that activity, such specification demands synchronous coordination, co-operation and many trade-offs before being accomplished. In order to manage and execute the task, design engineers and logisticians use proprietary tools and specific inter-functional procedures as interface tools.

Problem here is that design is almost finished, due to the fact that main decisions are already been made and design solution for each component is chosen. Interfacing spaces (regular meetings for bill-of-materials specification) are dedicated to diffuse project information, plan and organize logistics processes according to product design structure, as preparatory stages before assembling first machine prototypes.

Between these periods there is a gap with no interfacing (as shown in figure 1). Specifically, the lack of interactions during a critical period of the design process (from concept generation up to detailed design phase) creates an asynchrony between designers and logisticians about the evolution and the sharing of design information and knowledge along the project, a communication issue already verified in other studies [18, 19].

From designer's point of view, they do not have support (logistician's involvement, tools, knowledge) for understanding logistics requirements and developing technical solutions for matching them during design activities. Also, we have observed that some requirements evolve and change along the project and the lack of knowledge about these changes usually lead to late conflicting situations with logistics. Thus, designers prefer postponing discussion related to logistics requirements until procurement bill-of-materials definition phase, where interface with logisticians is mandatory, but possibilities for changing design are very low.

From logistician's point of view, major problem is the way that product is split by designers and process engineers (by module) does not corresponds to the distribution of components in the product supply chain (for example, splitting by purchased sub-assemblies or module parts and by strategy for supplying them). As a result, information embedded into current product modeling like 3-D CAD/CAE models usually developed and used all along concurrent design activities is not appropriate for anticipating logistic scenarios in terms of component physical flows. In effect, the logistic view of the product is achieved late in the project time-line, through bill-of-materials specification.

That description shows that interface between engineering and logistics is not properly structured for allowing co-operation during project early phases, even if the NPD process we have studied emphasize product-process integration. Indeed, the lack of appropriate tools obligates logisticians to stay on the sidelines of concurrent design activities, waiting for phases of the project where information and knowledge about the product are well structured and accessible in order to specify procurement bill-of-materials. These problems were the starting point for defining the Logistic Profile.

## 4. Logistic Profile definition

In general terms, basic assumption in our approach is that each intermediary solution of design implicitly entails logistic attributes or characteristics, which demand a translation step in order to be suitably captured and analyzed from a logistics point of view. In our conception, the translation cannot be automatic, but it requires interaction, sharing and co-operation to be accomplished. Such translation is the first step before generating a support of interfacing between logisticians and designers during Concurrent Engineering activities. As result of interfacing, the intermediary solution of design should be improved from a logistics standpoint.

Based on this, we derive some preliminary assumptions concerning Logistic Profile's functionalities:

- Activities centered on Logistic Profile must structure the engineering-logistics interface, shifting strong interfacing period from bill-of-materials specification phase to previous stages of design process, for filling the gap shown in figure 1.
- Logistic Profile should assist logisticians and designers to translate on-hand information about intermediary solutions of product design in terms of tendencies on logistics processes. The aim is not being precise or exact, but just to give a rough assessment for anticipating appropriate logistics treatment (management and handling) to be addressed to a component in design (*i.e.*, a sub-system, a module or a part that integrates the final product), knowing that logistics processes can also change and evolve for supporting an innovating product design.
- It must allow designers to be aware about logistician's assumptions related to the management and handling of each product's component, as well as effectively to support trade-off negotiations between them during Concurrent Engineering meetings, for example to choose a solution alternative for a component design.

Therefore, Logistics Profile is a conceptual tool for structuring the interface between designers and logisticians, first allowing the translation from design view into logistics view and then supporting the information sharing, trade-off negotiations, as well as co-operation during early phases of NPD projects for improving design solutions.

In the literature, profile identification has been associated to a specific product characteristic or a life-cycle stage, for example environmental profile [20], ecological profile [21] or manufacturability [22], in order to drive designer's decision making. In our approach, *Logistic* term means logistical characteristics associated to intermediary solutions for a component in design and *Profile* term concerns the support for approximately depicting such characteristics.

Hence, the question is how to represent suitably Logistic Profile, knowing that information is ill defined, incomplete and changing during early phases of NPD projects. We propose initially a general model for the Logistic Profile concept.

## 4.1 Logistic Profile Model

The Logistic Profile model comprises three main elements: *variables*, *profile drivers* and *profile chart* (figure 2). It generalizes the method for translating designer's view into logistician's view and prescribes a representation support for assist both logisticians and designers in their interfacing.

Variables are generic and independent of a specific product or project, but they are dependent of specificities of the company strategy and context. Variables are to be defined for supporting designers and logisticians interfacing during any product development project. Eventually and according to the specificity of each situation, variables may be updated or reviewed at project early phases, for example, concurrently to the requirements definition.

We identify two sets of variables: *Product Design-Logistics Interface* and *Logistics-specific*. The first set addresses variables related *simultaneously* to product design and logistics activities (for example, component's weight, maxi dimensions or material type). The latter one is specifically associated to logistics (for example, component's procurement type, inventory turns, storage location or lot size).

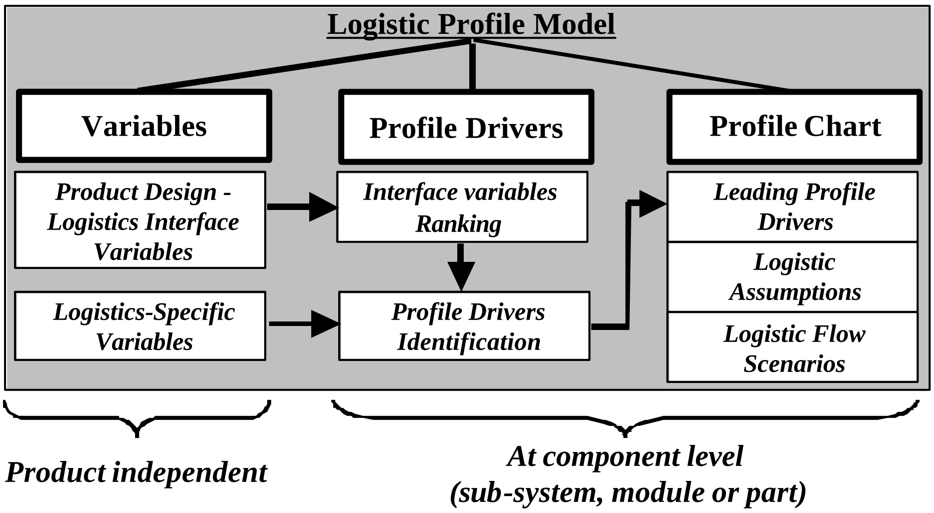



Figure 2. Logistic Profile model and its main elements (arrows point out the steps for defining a Logistic Profile).

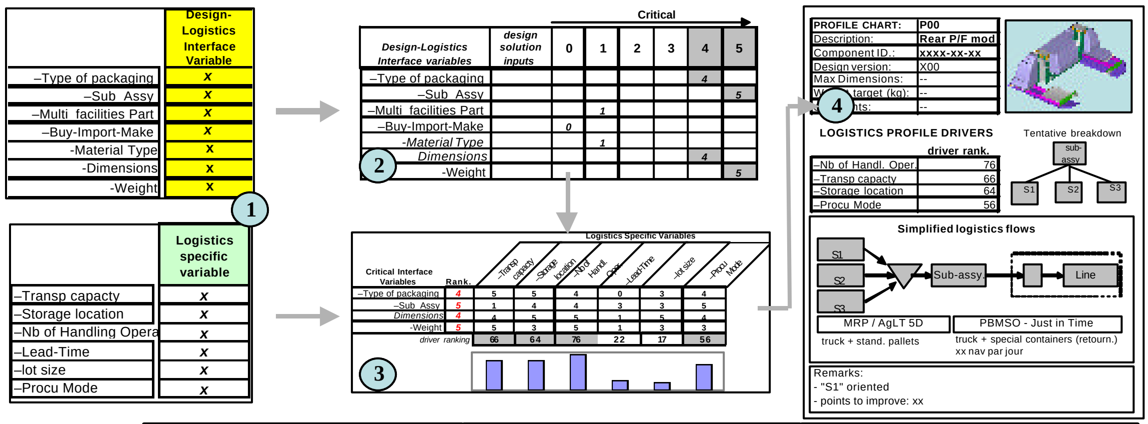
Profile drivers are at product's component level (sub-system, module or part) and they indicate which variables are critical for a particular component in design. Drivers are obtained in two steps and the first one consists in assigning a qualitative ranking for interface variables. This ranking indicates from designer and logistician standpoints which interface variables drive a given component design solution. Second step is to identify leading drivers by measuring impact of interface variables previously ranked in comparison with each logistics-specific variable.

Finally, Profile chart represents the support for interfacing and it depicts the Logistic Profile of the component in design. Considering that leading profile drivers are just indicators for describing logistic flows, logisticians have to make their own assumptions for building logistic scenarios taking into account characteristics of the given component design solution. Thus, the profile chart contains all leading profile drivers, the logistic flows scenarios, as well as main assumptions made for properly representing logistics view. The question is how to define each model's component.

## 4.2 Defining components of the Logistic Profile model

The model entails four main steps to feature a Logistic Profile of a given design solution for a component (figure 3). However, there is not a unique and special manner for defining each one, so current engineering tools (as QFD, FMEA, incidence matrix or clustering techniques, among others) can be applied. Most important is that both designers and logisticians are able for interacting at each step of Logistic Profile development and use, leading to build a structured interface between them.

a) ***Step 1: Identifying and classifying Logistic Profile variables***. As variables are product-independent, designers and logisticians can define them just once as a preliminary step before starting a NPD project. In our case, we worked with a cross-functional team (designers, logisticians, and process engineers) during brainstorming sessions. To aid the task, we use as information sources some QFD matrixes issued from previous projects, as well as logistics studies and checklists. Thus, we have arrived to a global set of 51 variables, which express specificities of company's NPD process and logistics organization. In a second step, we classified each variable as product design - logistics interface or logistics-specific (some examples in ❶ on figure 3). Sometimes, this frontier between variables is not clear and team members have to justify their classification. This task is crucial not only for tailoring Logistic Profile approach for company's particular case, but mainly for introducing and legitimizing the concept with team members before starting design.




| | Variables ① | Profile Drivers ② ③ | Profile Chart ④ |
|---|---|---|---|
| **Product structure level** | - | *Component level (sub-system, module or part)* | *Component (sub-system, module or part)* |
| **Responsibility for task execution** | *Designers and logisticians* | *Designers and logisticians* | *Logisticians* |
| **Main information sources** | *QFD matrixes; checklists; logistics studies.* | *Funct. Requir.; Prelimry. 3-D CAD models; Product Data Manag. Syst.; Logistics Manag. Systems* | *3-D CAD / CAE models; product Data Management System; Logistics Manag. Systems* |
| **Deliverables** | ***Product design – logistics interface variable set; logistics-specific variable set*** | ***Logistic profile drivers for the specific component in design*** | ***Logistics assumptions; Logistics scenarios for the component in design*** |

Figure 3. Four steps for developing the Logistic Profile.

b) ***Steps 2 and 3: Ranking interface variables and identifying Profile drivers***. This task is product and component-dependent, being carried out for each design solution, so responsibility for the task is shared between designers and logisticians. First, we apply a scoreboard ranging from 0 to 5 (from less to more critical, as shown in ❷ on figure 3) based on preliminary inputs from designers (module breakdown, preliminary 3-D models, functional and technical requirements, among other sources). As an example, for a particular module of the machine (rear platform), we identify *type of packaging*, *sub-assembly, maxi dimension*, and *weight* as critical interface variables (ranks "4" or "5", as shown in ❷). The second step is to rank these critical interface variables by comparison with logistics-specific variables and we have proposed a QFD-like matrix (shown in ❸ on figure 3). Thus, we associate a qualitative measure (also ranging from 0 to 5) for each correlation *[critical interface variable x logistics-specific variable]*. In our example, four logistics-specific variables have been evaluated with higher values: *number of handling operations*, *transportation capacity*, *store location*, and *procurement mode*, respectively, becoming leading profile drivers for the given component solution.

c) ***Step 4: Building Profile chart.*** This task is under logistician's responsibility, as the chart represents logistics view of the components design solution. Taking into account leading drivers, they build assumptions concerning information and physical flows. Logistics scenarios are represented by block diagrams, with all suppliers, inventory locations, lead-times and supply strategies (MRP, Kanban, etc.), as represented in ❹ on figure 3. Indeed, at the early phases of the design, all these decisions are not yet made, and assumptions about scenarios reflect the Logistic Profile incertitude. The profile chart allows logisticians to structure information in a suitable manner before analyzing if the Logistic Profile for the given component is aligned with logistics strategy and requirements. For this, we may use existing information about logistic processes for a known component (i.e., current product) or else prescribed logistic scenarios at strategic level. In our study, we have proposed to team members four classes of scenarios for comparison: S1 = {Effective, not critical} as reference to be achieved; S2 = {Effective, but critical} as acceptable according to risk level; S3 = {Ineffective} to avoid in design; and S4 = {Innovative} to be developed. Such scenarios are case-dependent, according to specificities of each logistics organization and the result of such comparative analysis is to know if the Logistic Profile for an intermediary solution of design is roughly good or not.

Nevertheless, we recognize that not all components of a product are candidates of trade-off negotiations between engineering and logistics, but particularly components considered critical or innovative for both team members for avoiding excessive generation of Logistic Profiles. If a given design solution indicates a Logistic Profile that is not well aligned, logisticians can identify critical points and build arguments for improving it during project's regular meetings with design engineers. In such a way, Logistic Profile evolves with product design. Question now is how design engineers and logisticians would actually interface for developing and use Logistic Profile during concurrent design activities.

# 5. Interfacing through Logistic Profiles

Here, we describe the periods of interfacing between designers and logisticians through Logistic Profile tool that aim to multiply opportunities for co-operation and synchronous information sharing, as well as filling the interfacing gap shown in figure 1. Hence, we distinguish two main phases (figure 4): the Logistic Profile development and the Logistic Profile in use.

The first phase starts *outside* a particular NPD project frame, given that it comprises a preparatory task of identification of variable sets. The second phase is centered on the use of Logistic Profile charts as support for information/knowledge sharing, co-operation and negotiations that take place during concurrent engineering activities, particularly regular project meetings.

We observe that this interfacing phasing cuts across classical stage-gate phasing as defined in NPD models. First, interfacing begins before a development project and second, it shifts the prescribed interaction period from the end of detailed design phase to the concept generation phase, allowing a synchronous evolution of knowledge about the product and its logistics.

## 5.1 Interfacing Phase #1: Developing the Logistic Profile

Interfacing activity here concerns the co-operative development of the Logistic Profile model, more specifically, the variable sets and profile drivers identification. First, defining and classifying interface variables before starting a specific project allow designers and logisticians to explain and share their own point of view about design activity and logistics processes, respectively. According to our own experience, designers and logisticians use analogy with other projects for explaining and justifying an interface variable, which permit to create a shared understanding about the concepts behind the variable, minimizing misjudgments and late conflicts during concurrent activities, as we have observed during some project meetings, when a specific variable (for example, "lead-time" or "module") has initially acquired different meanings in logistics and in design.

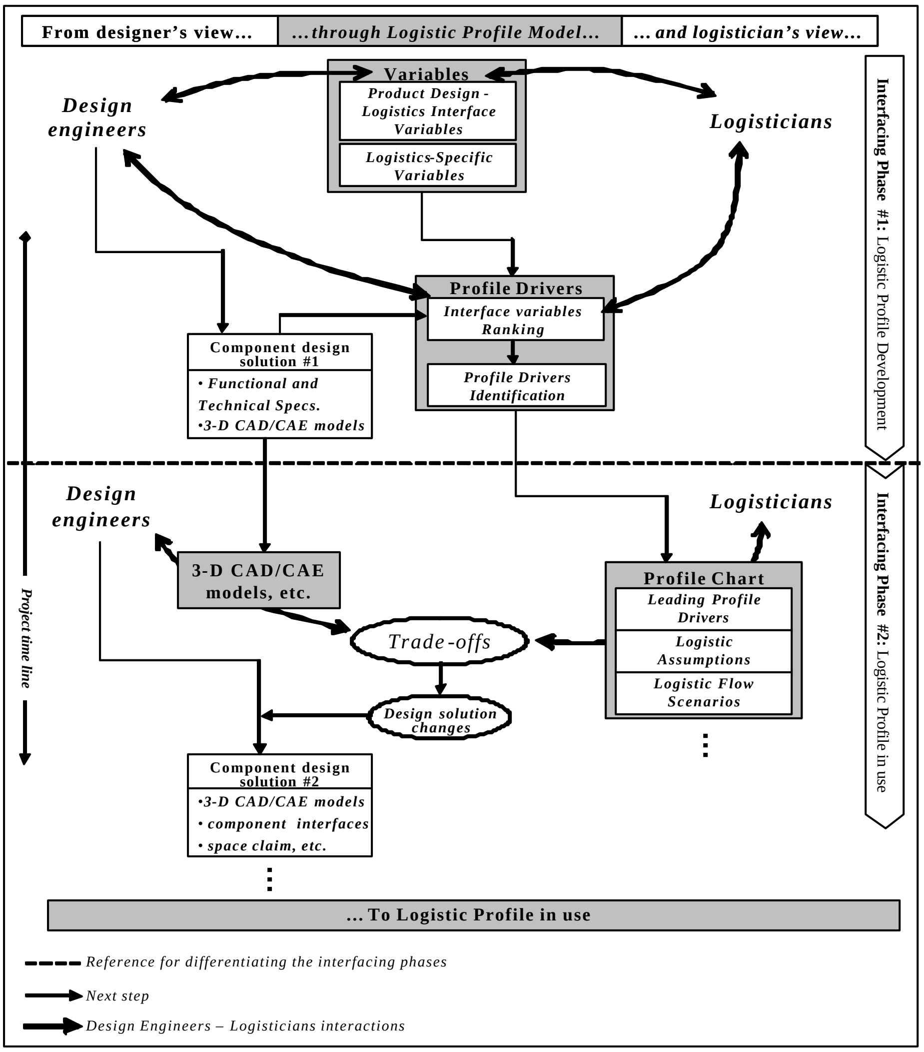



Figure 4. Interfacing phases trough Logistic Profile.

Second, considering a particular NPD project (the project time line's arrow in figure 4 begins after the variable sets definition), profile driver identification and assessment depend of particular product components, but these activities have to be executed interactively as soon as preliminary design solutions come out and regular concurrent engineering meetings are natural spaces for developing these tasks. The variable raking results of negotiation, because it concerns both product design and logistics processes management.

After ranking interface variables, logisticians are in charge of building profile charts, which allow them elaborate their arguments before negotiating potential improvements with designers, during the second interfacing phase.

### 5.2 Interfacing Phase #2: Using Logistic Profile during project regular meetings

In this interfacing phase, designers and logisticians identify profile drivers through the information provided by an intermediary solution for a component design (#1 on the figure 4). Then, logisticians build profile charts that will share the workspace with product models (3-D CAD/CAE), checklists, financial analysis sheets, and other supports often used during regular meetings, as well as in design and project's reviews. Profile charts offer the support for logisticians effectively interact with designers who will be aware of potential impacts of their solution on logistics processes and main assumptions made by logisticians about the component in design as well. Potential improvement on solution #1 constitutes a solution #2, as indicated. Such interactions represent an interfacing cycle that evolves all along the early phases of a NPD project and aims designers and logisticians build and share information and knowledge about each component in design. The core deliverable of interfacing cycles is a design solution that integrates logistics point of view.

We believe that including profile charts as support of interfacing changes the logistics paradigm of having complete and consolidated information about the product, because Logistic Profile is based on ill-defined information concerning product design. The crucial point here is that product nomenclature or bill-of-materials are not on the center of discussion between designers and logisticians, therefore changing completely the relationship between engineering and logistics in NPD projects. When procurement bill-of-materials is to be defined at the end of the detailed design phase, both logisticians and designs will already be acquainted with main constraints related to logistics and product design and potential solutions for managing them.

## 6. Conclusions

Evidences of our research reveal that current product-process integration approaches in terms of engineering design process and tools are neither suitable to integrate logistic needs into design nor adapted to allow effective interfacing between designers and logisticians. Both have to be able to interface not only in late phases of development, when product design is almost frozen, but in all NPD project stages in order to support project stakeholders in making decisions that effectively integrate logistical issues.

Based on an empirical research in the heavy-equipment industry, the foremost contribution of this paper is the proposition and development of the Logistic Profile concept, a tool that assist the interface structuring, translating the product design's point of view into logistics point of view and supporting tradeoffs between logisticians and designers all along concurrent engineering activity during NPD projects.

After working with the team members who have contributed to the Logistic Profile development, we are confident to stress that this tool can also work as a vector for mutual and growing learning between design engineers and logisticians, despite their particular views and requirements about the product and the project. If in a first moment this mutual learning requires a synchronous and well-structured interfacing during a NPD project, it surely generates tangible opportunities for guiding the development of design-logistics integration rules that allow a more autonomous concurrent design work. Besides developing integration rules, one of the perspectives for further development is to use Logistic Profile as a structured information platform for identifying and assessing logistic costs drivers.

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