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# Integrated usage of simulation tools in product development

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## Abstract
Demands of product development are getting tighter. There is less time for the development and at the same time customers require more customised products. Therefore faster design methods have to be developed. The usage of simulation is one way to solve these problems. Simulations can give a great amount of helpful information to designers in the very early phase of the product process. The usage of different types of simulation tools is a challenging task in product development and the process has to be well planned. A large amount of data is transferred during the process, therefore the data management constitute to very important matter.

*Keywords: Simulation based design, Conceptual simulation, Multibody simulation.*

## 1 Introduction
Product development is getting challenging all the time. Time-to-market becomes shorter and at the same time demands of the products are getting more rigorous. Thus more information about the product is needed in the early phase of product development. These are some factors that forces manufacturers to greater usage of Computer Aided (CAx) tools in product development [1]. In addition design costs are small part of overall costs of the product but the design phase has biggest influence to the definite costs [2]. Efficient usage of multidisciplinary CAx programs can reduce design time, manufacturing costs and increase communication and collaboration inside the company. [3, 4]

Usage of dynamic simulations and computer aided analyses in mobile working machines is going to increase in the upcoming years. This is because tests made using physical prototypes are expensive and time demanding. The dynamic characteristics of the products are important when estimating the product's lifetime [5, 6]. At the moment there exists a wide variety of CAx tools for versatile areas in product development. However, a program which unites CAD and dynamic simulations is missing [4, 7].

Prototypes are inevitable in product development thus prototyping phase can be found in most familiar product development theories [8, 9]. Virtual prototyping enables to analyse the effects of design choices to the overall performance of the product [6]. In 1970's product development begun by building the product and then testing and analysing it. In 1990's the designers first analysed the design and then the product was build [1]. This ideology is possible to take even further and quicker using up-to-date CAx tools.

This research was part of a research project called Konemasina which was organised by the VTT, the Technical research center of Finland. Six globally leading heavy industry companies and three technical universities participated in the Konemasina project. The other research areas were real time simulations, human machine interaction, and dynamic simulations of nonlinear components.

## 2 Objectives

The objectives of this research were to study requirements of integrated usage of different category simulation tools and to develop a process model which would emphasize earlier usage of simulation in product development. Another important objective was the reuse of simulation models and information and to find a solution for importing this data in an effective way to a product data management (PDM) system.

## 3 Methods

During the research the simulation based process model was created and it was modelled using an IDEFØ-flowchart [10]. IDEFØ is a standardized, purpose-built tool for modelling decisions, functions and actions in an organisation or a system. The models are very straightforward and therefore are usually interpreted correctly without prior knowledge of the semantics of the system. IDEFØ models use only a very limited amount of symbols, with the decomposition technique they can be focused onto the required level of detail. In figure 1 the functioning of the flowcharts function boxes is presented. The operations of one function box can be represented more detailed with new diagram. In that case the number of the diagram, including the detailed information, is visible below the function box.

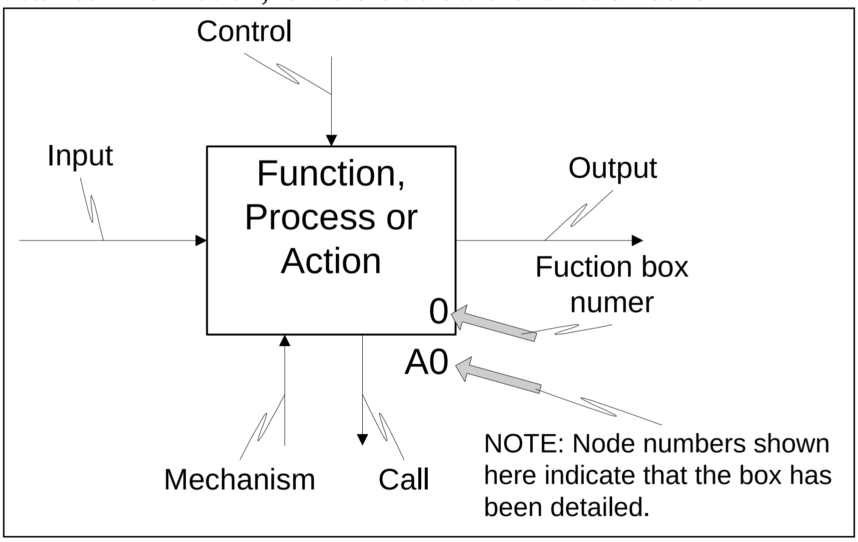


**Figure 1. The basic function of IDEFØ activity box**

In this research two different programs were chosen for closer examination. Firstly, CATIA V5, a 3D CAD program from Dassault Systèmes and secondly, the MSC.Software's ADAMS which is a program for the dynamic simulations of multibody systems (MBS). These programs are used in many globally leading companies in the area of mobile machine industry, so they are a good base for the research. Along with our own research, information was gathered by interviewing design managers and ADAMS specialists.

## 4 Transferring models

In this research numbers of multiple types of simplified models were used for testing the model transfer. The basic transfer operation is same regardless to the size of the model. Therefore smaller models were adequate for studying the data transfer.

As is usual, the data transfer between two different types of programs became a problem. It is not possible to transfer native CATIA files directly to ADAMS. Therefore a unifying file type is needed. ADAMS supports many common standard CAD file types, such as STEP and IGES in general level but problems arise in accuracy and the models parameters. ADAMS was incapable of calculating parameters (mass, inertia) form IGES models and in STEP type it is not possible to import assemblies. The solution for model transfer is a Parasolid file type. By using Parasolid it was possible to import assemblies at once. Also the features (corners, center point of holes, etc.) of the models could be used as reference points when defining a model in ADAMS. These procedures are possible because Parasolid is the core file type of ADAMS.

Additional problems arise in case of CATIA, because Parasolid is not an exporting option in CATIA. Therefore a third party translator is needed for enabling the model transfer (figure 2). These translators can read native CAD files and then export them in the desired format. Files can be translated also by an external company.

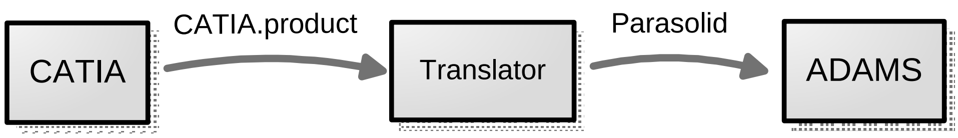


**Figure 2. Process of translating file to other format**

The disadvantages of third party translators are the extra work for the designers who have already tight schedule. Also security issues arise in case external companies are used. Some of the information could be classified so there has to be a trusted relation between the companies.

## 5 Modularisation of simulation models

With the latest simulation tools it is possible to simulate the whole product including all small specifics but this way the simulations become very large and tedious to work with. Hence simulation models should be divided into smaller functional modules. These modules have to be modular in a simulation sense, meaning each module is simple to replace with a new one and the modules can also be simulated independently. ADAMS models are based on command files. One model is one command file so subassembly concept is not considered by ADAMS. The solution for this is the possibility to call other command files from a main command file. This enables structuring the simulation model in a tree structure (figure 3) [7].

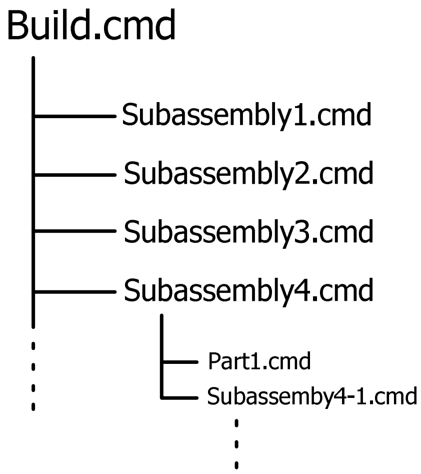


**Figure 3. A tree structure constituted using ADAMS command file**

By building and structuring the simulation model as shown above, performing and managing the changes becomes easier. Also the different model variations are faster to create, because a change in one module only requires changing the name of that subassembly or part.

## 6 Simulation Based Product Development

In the beginning of this research, the focus was on transferring the geometrical models from CATIA to ADAMS. As the research proceeded it became evident that information transfer and data management was more important than transfer of complete geometrical models. The dynamic simulations do not need all the details or even all the parts that exist in a complete product model. Another factor is that a designer working with CATIA cannot make changes directly to the ADAMS model or vice versa. Instead a request for modifications is sent to the designer who is responsible for the simulations.

In figure 4 is presented the modelling process of the product development. The preceding phase is sketching and construction of concept ideas. Conceptual simulations are begun based on the created sketches and the information from the previous projects. The conceptual simulations are simulations where a very coarse model is used. The idea is to get basic parameters (joint dimensioning, mass estimations) for the next phase. With the basic parameters the design can be taken to the embodiment design where detailed information about the product is developed and furthermore use computer aided design (CAD) to specify the design ideas. The CAD models give accurate parameters of the parts that are updated to the MBS model. Finite element method (FEM) is used for analysing the structure and lifetime of the product. For the FEM analysis detailed geometry comes from CAD and information about imposing forces comes form MBS. However, development processes are never this straight forward and iteration loops are needed to finish the optimized product structure.

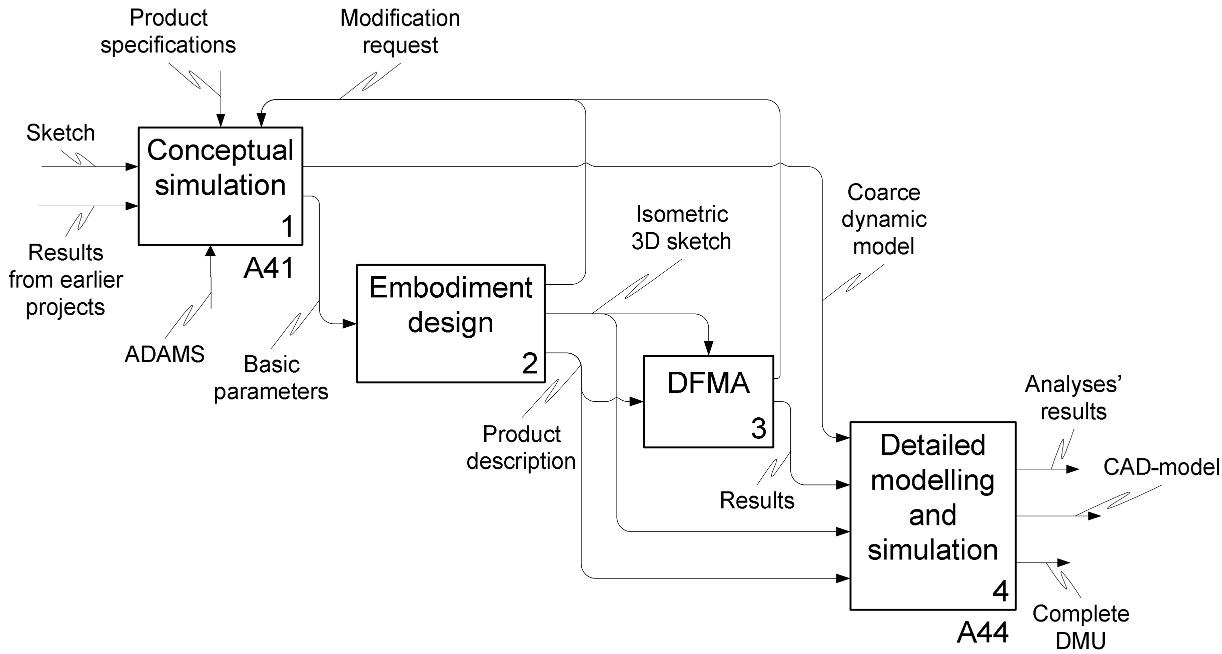


**Figure 4. Product modelling phase and the information flow in it. (A4)**

The feedback and modification request are important part of the process. It is practically impossible to create an optimised solution for the problem in one go. Concurrency of the different phases is also important factor considering the limited time of the product development process.

### 6.1 Conceptual simulation

At present, a typical way to start the product design is to start with CAD modelling. The disadvantage of this method is the slowness of making changes. Also the too detailed geometry at the beginning of the product development obscures the meaning of the geometric shapes. In this way the design decisions are not necessary based on best knowledge about the product [11]. Changes of one part effects many other parts and even with well parameterised model these changes cause plenty of work. By changing the process to top-down design, bigger decisions can be made in a later phase and at the same time much more information can be found to support all decisions.

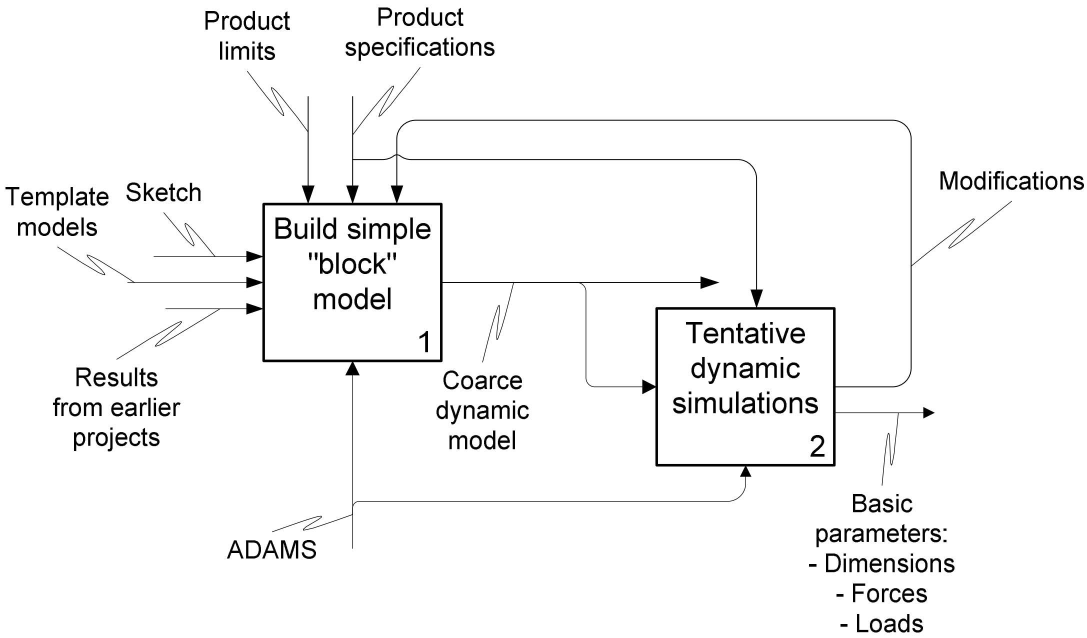


**Figure 5. Conceptual simulation phase (A41).**

In most cases, product development is incremental development, redesigning of earlier products [12]. Therefore there exists abundantly information which can be used for example to estimate the masses of parts. Based on this existing information, a coarse MBS-model is fast to build. This model can be build using simple basic blocks. When searching main parameters of product the coarse model is accurate enough. As an example, searching the positions of joints in a mechanical structure is fast because e.g. collisions and geometric restrains are not important at this phase. If the results of simulations are not satisfying, parameters are easy to change and therefore multiple different solutions can be simulated in a short time. The results of the conceptual simulations are basis for the embodiment design, where all the details of part parameters (geometric constrains, 3D-space requirements, manufacturing methods, materials, tolerances, instructions etc.) are designed (figure 5).

### 6.2 Embodiment design

After conceptual design comes the embodiment design. In the embodiment design constructions of the parts are developed [8]. At this point designers need as much information as possible to make correct decisions. MBS simulations yield information about forces inside the product's structure. Conceptual simulations give data which is accurate enough for background information for the embodiment design. Concurrently with embodiment design the manufacturing and assembly should be taken into consideration. Design for manufacturing and assembly (DFMA) is an important part of the design process nowadays because optimization of these factors can lower the production cost radically.

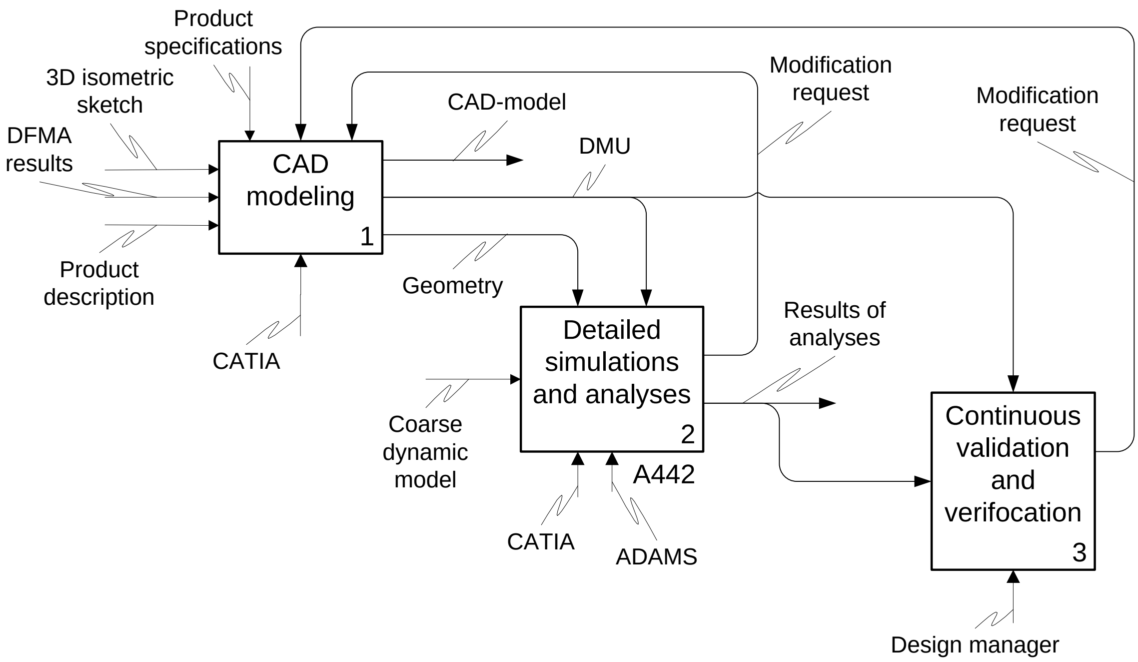


**Figure 6. Modelling and more detailed simulations of the product. (A44)**

When all the detailed information is developed, creating the CAD model is fast process. Present CAD tools enable an efficient 3D modelling. Major software manufacturers also offer additional tools for different analyses e.g. FEM analyses. Accurate geometry is needed for structural analyses. Another important factor is the forces imposing inside the product between the different parts.

The information flow between different phases has to be fast and error free. Another factor is the freshness of the data. All simulations and analyses have to be based on the latest data. Due to multiple iteration loops simulation data is changing frequently and needs to be updated as frequently [4].

### 6.3 Detailed simulations and analyses

From CAD model parameters of the product can be updated. Most important ones for dynamic simulations are masses and inertia of the parts. At this point of the designing the geometry of the product is accurate so the simulations become more realistic. The detailed geometry can be used for example to examine possible collisions and to assure the kinematics of the product.

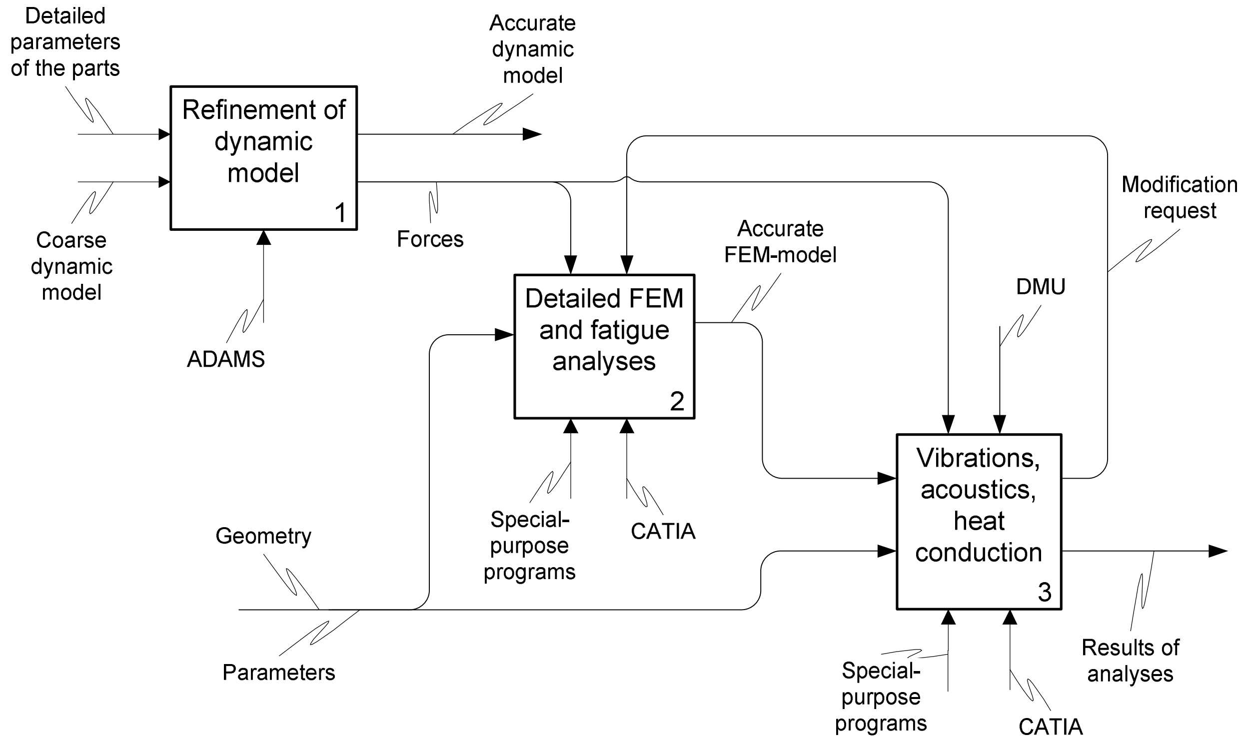


**Figure 7. Detailed simulation and analyses. (A442)**

In figure 7 is presented data and model flow between different tasks of detailed simulations and analyses. As can be seen, some analyses are possible to make by CATIA but some problems need special-purpose programs which are usually made for one specific problem area.

## 7 Verification and Validation

By model verification, designers confirm that the model is built right. Model validation assures that the model is behaving as it should be, in other words, the designers building the right model [13].

Simulation is an effective method to study the important aspects of the product. However, without verification there is lack of trust to the simulation results. Simulation models are, in most cases, very large and finding an error can be impossible. Therefore as much verification as possible is needed. The results of analyses are compared to the results of tests with physical prototypes. A partial physical prototype is good solution to get fast information and with minimal costs. In this way testing can focus on one certain area or characteristic. Other sources for measured data are the component manufacturers, material tests and earlier projects. Experience and tacit knowledge of the modellers hastens the creation of flawless models.

## 8 Product data management

In this research CATIA and ADAMS was chosen for a closer examination. As discussed, the file types and the type of the programs are quite different. Thus, direct model transfer is not possible or even necessary at the later phase of product development when the level of details is very high and models have to be simplified for simulations. Instead, parameters and modification requests are sent from one designer to another (figure 8). To control this information flow a good PDM system is needed, where all the data is collected.

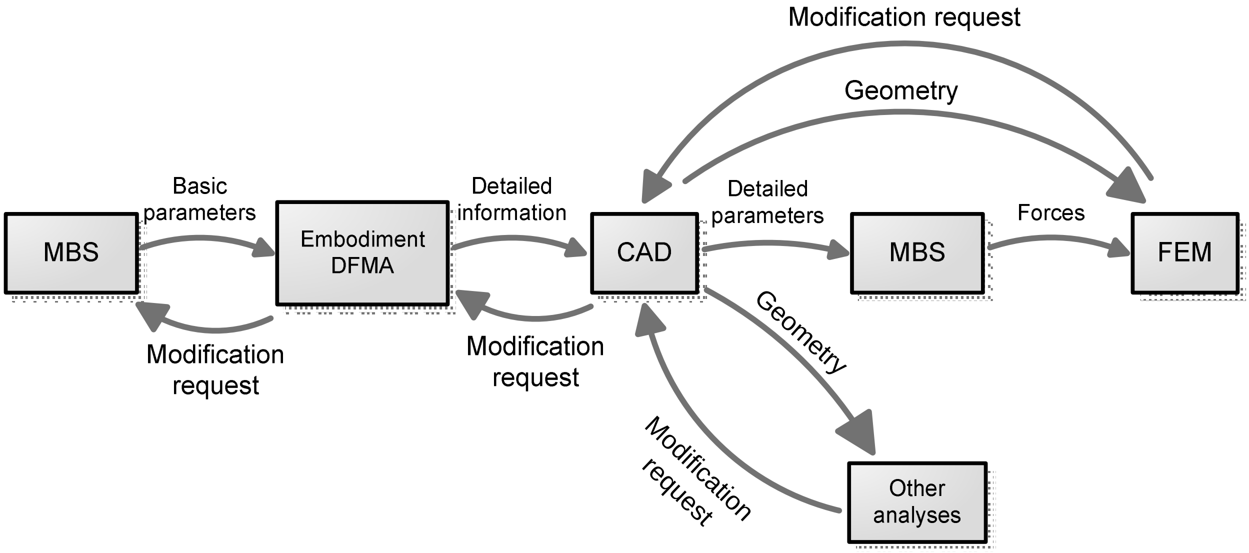


**Figure 8. Main characteristics of information moving during the product development**

The integrated usage of simulation tools is based on parameter transfer. The most recent data has to be available to all personnel who need it. In the PDM system the relationship and responsibility areas of designers and other personnel is also described. In this way information flow is clear, only the necessary data is sent to people who it truly concerns. The requirements and content of the different tools varies. The PDM system contains more than just the documents and models created during product development. The PDM system is another good tool, however it has to be configured to optimise its usage.

## 9 Conclusions

In the mobile machinery industry physical prototypes have had a very important role in product development. Because of the globalization in this industry area the responsibilities of product development have also spread globally. Therefore building of the physical prototypes is becoming more difficult. Thus the virtual prototyping is becoming necessary. With the latest CAx tools many multidisciplinary phenomena can be simulated with high accuracy.

The usage of modular virtual prototyping has been shown in this research. Also the required changes to the product development process are presented. The presented process model utilizes the usage of modern commercial software tools as: CAD, dynamic simulations and PDM.

The simulations should be started from the very beginning of the product development. In this way the designers will have a better understanding how the product works and how design changes alter the behaviour of the entire product. The usage of simulations needs to be planned well because simulations will always give a result but the correctness of the results is crucial.

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