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# A Methodology for Predicting the Effect of Engineering Design Changes

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**Abstract**

To sustain competition, it is necessary for designers to contrive changes in a product. These changes are often denoted in literature as engineering changes. The engineering changes when committed, can have percolating effects on other design aspects of the product, manufacturing processes, machines, materials, labor, operating time and cost. In order to implement an engineering change, it is necessary for designers to predict the effects on different stages of product development. We developed a methodology that would help in predicting the effects of engineering changes on the product and the manufacturing environment. In our work, we simplify the product and manufacturing environment into simple parameters that are imposed in a Design Change Prediction Matrix (DCPM). The matrix also stores the dependency between these parameters. Using the matrix, we developed an algorithm that would lead to development of a prediction tool in future.


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*Keywords:* Engineering changes, Design parameters, Dependency

## 1. Introduction

In the market, there exists major competition among products that are for similar purpose. Especially, the competition prevails among products manufactured by Small and Medium Enterprises (SMEs) [1]. The factors that are responsible for competition are technology evolvement, cost reduction, product aesthetics, and performance enhancement and consumer feedback [2]. In order to sustain this competition, it is necessary for the designer to commit design changes in the product [3]. The design change that is performed can affect supply-chain of the product in enormous scale [4]. In addition, it may affect the inventory, processes, transport and labor in the company [5]. The effect of design change can be huge or small (predictable) depending on the change involved [6]. Different aspects of Engineering change comprise a change in the material, property, new features, function, manufacturing, cost, color, embossing, power supply, component addition, or testing method [7]. Predicting an impact of design changes is necessary for implementation [8]. The decision making on whether or not the change has to be implemented, could lead to profit or loss [9] depending on effect of the change.

The implementation of design change not only requires prediction for decision making, but also strategic management of negative impact upon accomplishing the change [10]. For instance, consider a design change that requires an additional amount of specific material. The respective material has to be ordered well in advance so that production is not delayed. Hence, time balance along with quality and cost plays a vital role in change management [11]. In addition, there can be issues with labor acquaintance, power shortage, sales decline, quality control [12]. Hence, to preserve the objective of company while implementing a design change, there is need of feedback system [13].

An engineering change is understood in different perspectives throughout the literature. Jarratt et al. [14] defines an engineering change as: “An engineering change is an alteration made to parts, drawings or software that have already been released during the product design process. The change can be of any size or type; the change can involve any number of people and take any length of time.”

This definition by Jarratt [14] provides a generic information of engineering change applicable to any department or any stage of manufacturing. However, the


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definition lacks clue about the effects on production, cost, time, inventory and machines etc. Ulrich [15] states, reasons for change in a product as stated in his work, are up gradation due to technological advancements, necessary add-ons in the product, wear due to physical contacts, extinguishing components due to consumption and need for adaptation and flexibility to meet demands of various consumers [15]. Additionally, Ulrich [15] proposes that minimum change in a product is change in one component.

### *1.1. Background*

Researchers in the past have proposed various methods for engineering change management. Most of the significant work in the past was based on the Design Structure Matrix (DSM), developed by Steward [16]. It stores and represents the connectivity between different design elements of a product. The matrix proves to be a single domain for structuring all the knowledge that could possibly surround a product [17]. Cheng and Chu [18] used DSM to predict the impact of changes in a product within the product itself. For this, DSM of Roots blower was constructed and dependencies are evaluated. However, their work does not involve predicting impacts on manufacturing environment.

Clarkson et al. [8] use DSM as the basis for representing the prediction of change propagation. A case study was performed on Westland Helicopter, EH101. The dependency between various components is stored in a DSM. The prediction of change in one component upon others is evaluated using a correlation. This work seems to have performed a case study on a highly complex product.

Many researchers believe that visualization is necessary for change management. For instance, DEPNET (Dependencies Network) solution identifies different processes and connects those using arcs. The arcs that represent dependency are evaluated for completeness, variability, and sensitivity [19]. In addition, a work based on parameter linkages specifically uses tree structure to build change propagation paths [20]. In other work, a change is visualized as it propagates through multi layers such as product layer (Design), change layer (Change requests) and social layer (Engineers). The connectivity between the layers develops a basis for change propagation paths [21]. Kocar and Akgunduz [22] developed a model assessing priority of ECRs (Engineering Change Request). Ahmad et al. [23] managed to represent the effects of engineering change in a generic manner. In their work, the engineering changes are categorized as Requirements, Component, Function, and Design process. The case study was conducted on an AUTOBELL. The parameters falling in different layers are cross-mapped between each other and dependency is represented in a multiple domain DSM. The tool proves to be highly useful in visualization and quantification of effects of an engineering change. However, the database required for the tool has to be populated by a change management team that is well acquainted with the company's product development. It requires more time and money to be invested for the utilization of this tool.

Overall, the methods used in the past were able to assess changeability in different components of a product using DSM as basis. However, the methods do not explain how the data is being generated in the case studies. The authors do not hint the scope of transferring the methodologies into software. In few cases, where the platforms have been developed, the algorithms are not clearly explained. Complex products may have huge number of components that can be used as parameters in DSM and hence, it is doubtful that the majority of the methods addressing the complex products could be used in practical cases. However, it is possible to use DSM if such a complex system is not decomposed to very deeper levels. For instance, in an automotive, the ignition system has to be used as a whole component instead of breaking it down into parameters like primary coil windings, spark plug resistant etc. that exist in low systemic levels. Therefore, specificity of the change could not be achieved by applying such methods for complex products. Hence, we intend to develop a similar methodology that could be applied for simpler products manufactured by SMEs and use parameters that exists at very low systemic levels.

## 2. Aims and Methodology

The motive of our work is to predict the comprehensive effect of engineering design changes on various design aspects of a product and its manufacturing. We carried out the methodology on an example as explained in the later sections with respect to Stapler that we considered for case study. The database created for the product is used to construct a Design Change Prediction Matrix (DCPM) that acts as the basis for a prediction algorithm.

### *2.1. Data gathering*

A reverse engineering exercise for a Stapler was carried out in the Product Design and Realization Laboratory, at a premiere research institute. Reverse engineering helps to identify the basic design features of a product, materials used, required manufacturing processes and cost. The outcomes of reverse engineering can be utilized to build a database for the product [24]. As shown in Figure 1 (only few are labelled), the components of Stapler are found to be Plastic finger rest, Release clip, Lower leaf spring, Anvil, Base, Anvil actuator, Spacer, Spring, Pin, Staple Slide, Bottom Staple Guide, Upper arm, Upper Staple Guide, End cap, Upper leaf spring, Upper cover, and Plastic cover. In addition, Figure 1 (left) shows the approximate manufacturing layout of a Stapler company. The processes required to build a Stapler are blanking, bending, punching, painting and others. Few processes are grouped. The data thus collected, would be used as the data source in the prediction methodology.

### *2.2. Understanding the change*

The literature has different perspectives for engineering change. The definition as given by Jarratt [14] has been used worldwide. However, we recognize an engineering change as "an alteration of one or more components of a product that can be considered as a collective change in design parameters constituting those components; it can be introduced during product development or after product release at any point of life cycle; it can affect other aspects of design (structure and function), manufacturing (development), utilization (after product release) and overall performance of a company".