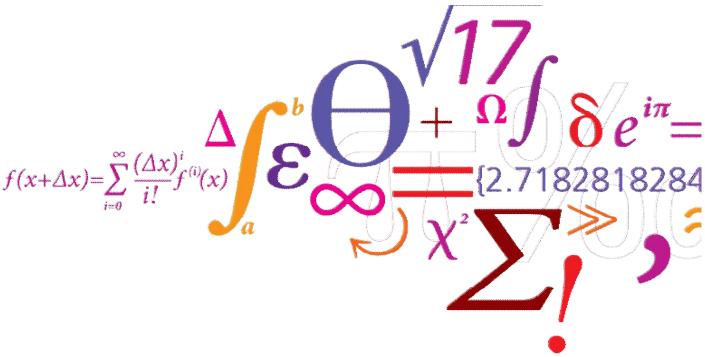
How to Analyze and Quantify Similarities between Configured Engineer-To-Order Products by Comparing the Highlighted Features Utilizing the Configuration System Abilities

Sara Shafiee
Lars Hvam
Katrín Kristjánsdóttir



DTU Management Engineering
Department of Management Engineering

HALDOR TOPSØE
CATALYSING YOUR BUSINESS

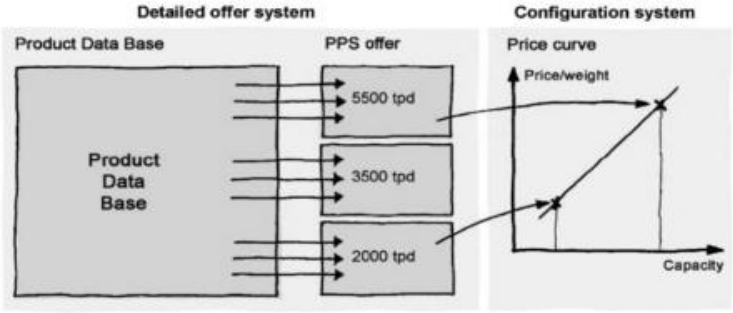
Agenda

- Problem statement
- The benefits from further research
- Related previous researches
- The suggested framework
- Ongoing case study

Problem Statement

"Lessons learned" is becoming a key factor for the improvement, in time and in quality, of operational processes

1. Excessive errors, too long time between sales and installation due to inadequate product information supply to the sales office, an excess of repetitive activities within the technical office, and a high rate of configuration errors in production [1].
3. According to Hvam et al. [2], price curves are not always beneficial.



[1] R. Magali and L. Geneste, "Search and adaptation in a fuzzy object oriented case base," *Advances in Case-Based Reasoning,* Springer, Berlin, 350-364, 2002.
[2] L. Hvam, N.H. Mortensen and J. Riis, *Product Customization,* Springer, Berlin, 2008

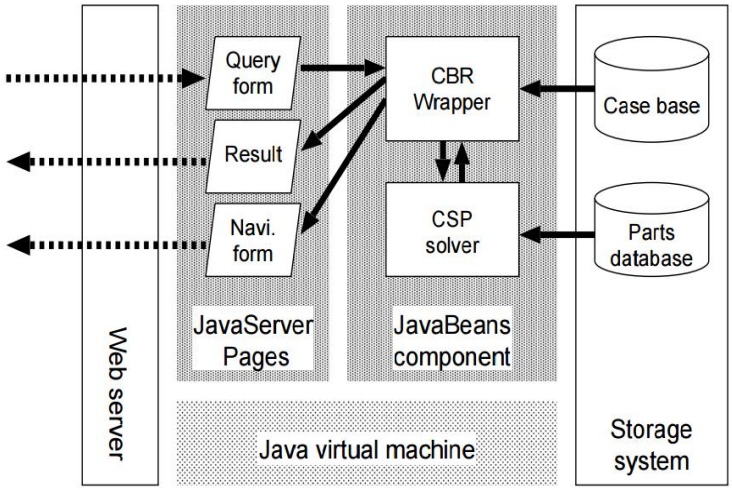
Benefits of Reusing Previous Projects

Area	Benefits
Management	1. Lean management by avoiding all the pre sales, production and sales activity that have been performed before.
Configuration system development	2. Reducing errors and increasing reliability of the configuration system.
	3. Facilitating the testing process for the configuration systems development.
Standardization, Product planning, Configuration system	4. Recommending previous successful projects to the end users.
	5. Basis for product standardization.
Product planning, management	6. Statistical approach to the products' information and market requirements.
Product planning, Configuration system	7. Improve the quality of the configuration system, lead time, manufacturing, sales engineering, etc.

Related previous researches

- Inakoshi et al. [1] propose a framework for product configuration that integrates a constraint satisfaction problem with a Case-based Reasoning tool (CBR):

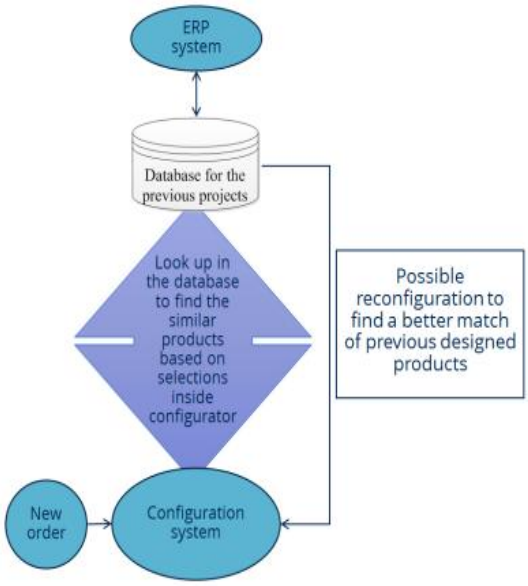
1. Case retrieval
2. Requirement formalization
3. Requirement modification
4. Parts database
5. CSP solver



[1] H. Inakoshi, S. Okamoto, Y. Ohta and N. Yugami, "Effective decision support for product configuration by using CBR," in *Fourth International Conference on Case-Based Reasoning (ICCBR), Workshop Casebased Reasoning in Electronic Commerce*, Vancouver, Canada, 2001.

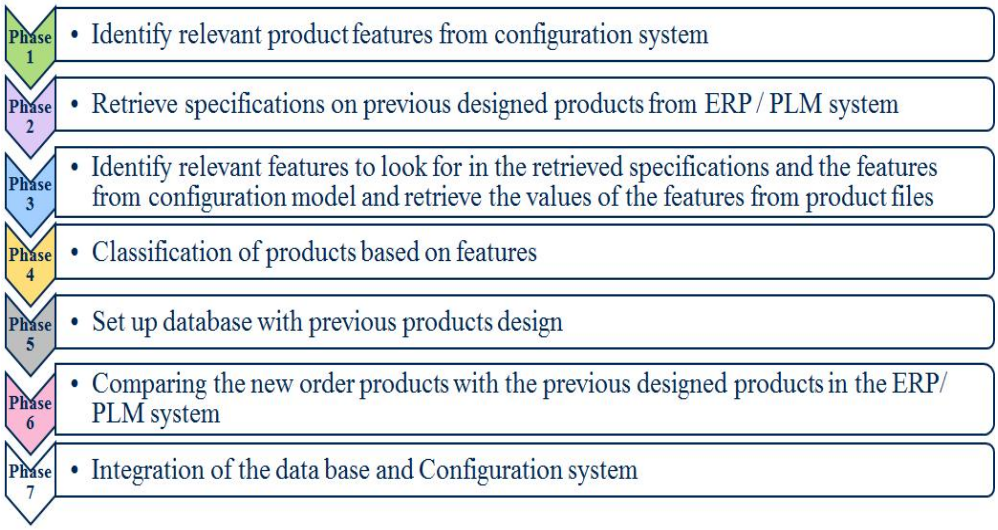
The Suggested Method for Comparing Product Features

The process of comparison in order to find similar projects



The Suggested Framework

- The framework provides a systematic way in order to create a database for the for comparison based on the currently available methods and tools



Framework

Phase 1: Identify relevant product features from configuration system

According to Ulrich, if an existing product has standardized and decoupled interfaces, the design of the next product can borrow heavily from the components of the previous product [1]

- ✓ Thevenot and Simpson [2] discuss a framework where commonality indices are used for redesigning the product families to align with cost reductions in the product development process
- ✓ E. Lopez-Herrejon et al. [3] introduce Software Product Line Engineering (SPLE) to represent the combinations of features that distinguish the system variants using feature models

[1] K. Ulrich, "Fundamentals of product modularity", in "Management of Design: Engineering and Management Perspectives, Atlanta, GA, Springer, 219-231, (1994).

[2] H. J. Thevenot and T. W. Simpson, "Commonality indices for product family design: a detailed comparison.," Journal of Engineering Design, 17, 2, 99-119, (2006).

[3] R.E. Lopez-Herrejon, L. Linsbauer, J.A. Galindo, J.A. Parejo, D. Benavides, S. Segura and A. Egyed, "An assessment of search-based techniques for reverse engineering feature models," Journal of Systems and Software, 103, 353-369, (2015).

Framework

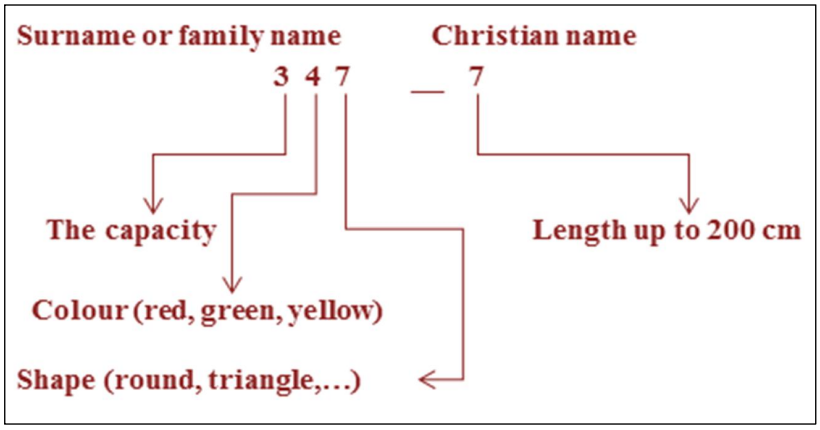
Phase 2: Retrieve specifications on previous designed products from ERP / PLM system

- Knowledge Discovery (KD) process elements:
  - ✓ Task discovery, data discovery, data cleansing, data segmentation
  - ✓ Model selection, parameter selection, model specification, model fitting
  - ✓ Model evaluation, model refinement, output evaluation

Framework

Phase 3: Retrieve features from product files and determining the values

British classification → Applicable in high level of similarities



1) T. W. Simpson, "Product platform design and customization: Status and promise," *AI EDAM: Artificial Intelligence for Engineering Design, Analysis and Manufacturing,* 18, no. 01, pp. 3-20, 2004.

Framework

Phase 4: Classifying the products based on features

- Group Technology (GT) method [1]: how to classify the needs for the product components and coding them.

- C4.5 algorithm [2]: It is used to generate a classification in form of a decision tree that is either a leaf indicating a class or a decision node that specifies some test to be carried out on a single attribute value.

  1. All the samples in the list belong to the same class.
  2. None of the features provide any information gain.
  3. Instance of previously unseen class encountered. Again, C4.5 creates a decision node higher up the tree using the expected value.

[1] J. L. Burbidge, *The introduction of group technology*, London: Heinemann, 1975.
[2] I. Sousa and D. Wallace, "Product classification to support approximate life-cycle assessment of design concepts," *Technological Forecasting and Social Change,* 73, 3, 186-189, (1980).

Framework

Phase 4: Classifying the products based on features

OSHAM systems	• Is generated in hierarchical graphical browser [1].
Unified Modelling Language (UML)	• Commonly used to represent domain experts knowledge. • Exploitation of the object modeling as an indexing base is suggested to allow a fast selection of potentially interesting objects during the similar case search [2].
Six Heuristics	• Is used for clustering and weighting the logical, syntactical and semantical relationships between feature names [3].
Product Comparison Matrices (PCMs)	• Can help to make a choice, where the aim is to visualize all the products characteristics through a metrical representation [4].

[1] T. B. Ho, "Discovering and using knowledge from unsupervised data" *Decision Support Systems,* 21, 29–42, (1997).
[2] R. Magali and L. Geneste, "Search and adaptation in a fuzzy object oriented case base," *Advances in Case-Based Reasoning,* Springer, Berlin, 350-364, 2002.
[3] G. Bécan, M. Acher, B. Baudry and S.B. Nasr, "Breathing ontological knowledge into feature model synthesis: an empirical study," *Empirical Software Engineering,* 1-48, (2015).
[4] G. Bécan, N. Sannier, M. Acher, O. Barais, A. Blouin and B. Baudry, "Automating the formalization of product comparison matrices," in *29th ACM/IEEE international conference on Automated software engineering*, 433-444, 2014.

Framework

Phase 5: Set up database with previous products design

Overview of database design in the following three steps [1]:

- Requirement analysis: Understanding of what data is to be stored in the database, what applications must be built on top of it, what operations are most frequent and subject to performance the requirements
- Conceptual database design: The information gathered in the requirements analysis step is used to develop a high-level description of the data
- Logical database design: Database Management System (DBMS) has to be chosen to implement the database design, and convert the conceptual database design into a database schema in the data model of the chosen DBMS

[1] R. Ramakrishnan and J. Gehrke, *Database management systems*, Osborne: McGraw-Hill, 2000.

Framework

Phase 6: Comparing the new order products with the previous designed products in the ERP/ PLM system

Case-based Reasoning tool (CBR) methodologies	• Are based on four tasks: Retrieve, Reuse, Revise and Retain [1].
Constraint Satisfaction Problem (CSP)	• Contextual knowledge corresponding to past cases • Regarding general knowledge corresponding to relations, rules or constraints that link design variables [2].
CYCLOPS	• First system to explore CBR in interactive design [3].
Fuzzy Search	• Method to define the neighborhood of the retrieved case to propagate domain constraints [4].

[1] Y. Avramenko and A. Kraslawski, "Similarity concept for case-based design in process engineering," *Computers & chemical engineering,* 30, 548-557, (2006).
[2] D. Navinchandra, "Exploration and innovation in design: towards a computational model", Springer Science & Business Media, New York, 2012.
[3] E. Vareilles, M. Aldanondo, A. C. De Boisse, T. Coudert, P. Gaborit and L. Geneste, "How to take into account general and contextual knowledge for interactive aiding design: Towards the coupling of CSP and CBR approaches," *Engineering Applications of Artificial Intelligence,* 25, 31-47, (2012).
[4] R. Magali and L. Geneste, "Search and adaptation in a fuzzy object oriented case base," *Advances in Case-Based Reasoning,* Springer, Berlin, 350-364, 2002.

Framework

Phase 7: Integration of the database with the product configuration system

- There is the possibility to integrate a constraint satisfaction problem (CSP) with Case-based Reasoning (CBR) tools for a product configuration system [1].

[1] H. Inakoshi, S. Okamoto, Y. Ohta and N. Yugami, "Effective decision support for product configuration by using CBR," in *Fourth International Conference on Case-Based Reasoning (ICCBR), Workshop Case based Reasoning in Electronic Commerce*, Vancouver, Canada, 2001. .

Plan for the Case Study

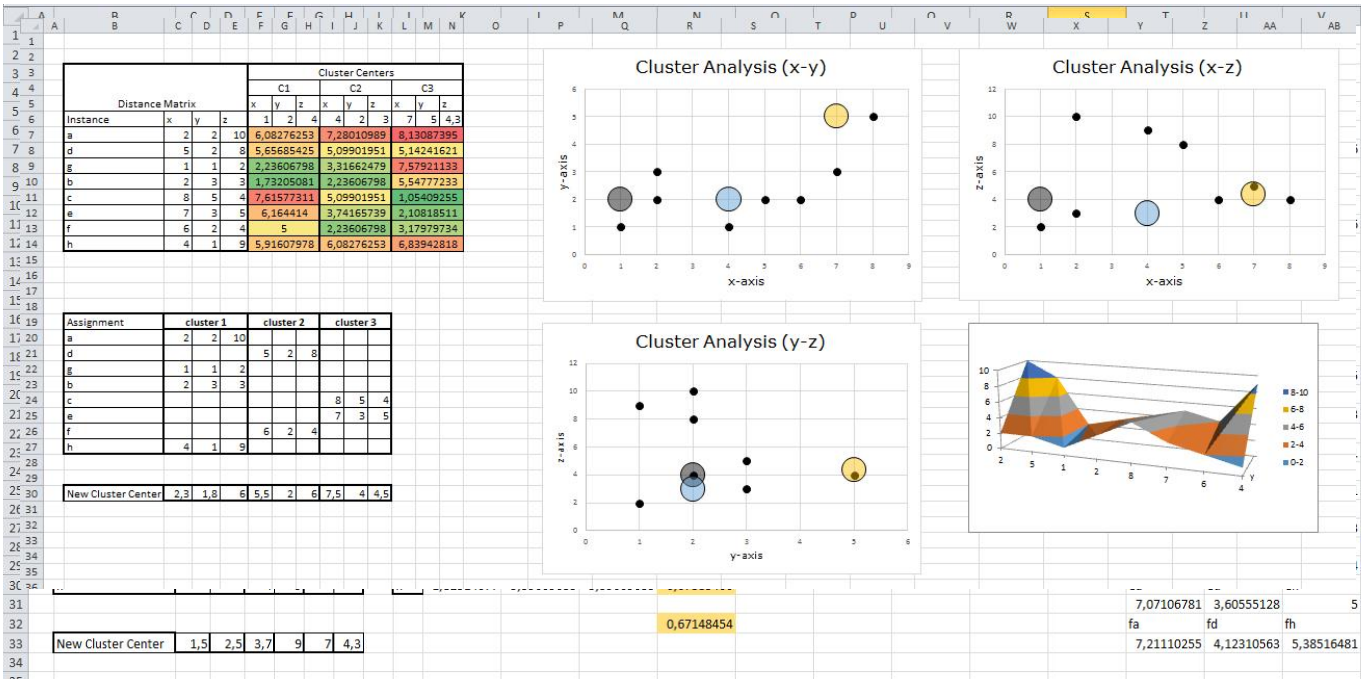
The case study should aim to find the major and minor drawbacks in the current framework and help us in developing the framework

1. Can we retrieve the products' features out of the ERP system?
2. Can we classify the products?
3. Can we make a data base according to the product features?
4. How to do the comparison between the new product and the previous designed products?
5. How to integrate the data base and configuration systems? How to make the user interface in the configuration system?

Ongoing Project at the company

Investigating about the available theories and methods:

- K-means method



Distance Matrix				Cluster Centers C1			C2			C3		
				x	y	z	x	y	z	x	y	z
Instance	x	y	z	1	2	4	4	2	3	7	5	4,3
a	2	2	10	6,08276253			7,28010989			8,13087395		
d	5	2	8	5,65685425			5,09901951			5,14241621		
g	1	1	2	2,23606798			3,31662479			7,57921133		
b	2	3	3	1,73205081			2,23606798			5,54777233		
c	8	5	4	7,61577311			5,09901951			1,05409255		
e	7	3	5	6,164414			3,74165739			2,10818511		
f	6	2	4	5			2,23606798			3,17979734		
h	4	1	9	5,91607978			6,08276253			6,83942818		

Assignment	cluster 1			cluster 2			cluster 3		
a	2	2	10						
d				5	2	8			
g	1	1	2						
b	2	3	3						
c							8	5	4
e							7	3	5
f				6	2	4			
h	4	1	9						
New Cluster Center	2,3	1,8	6	5,5	2	6	7,5	4	4,5

New Cluster Center	1,5	2,5	3,7	9	7	4,3

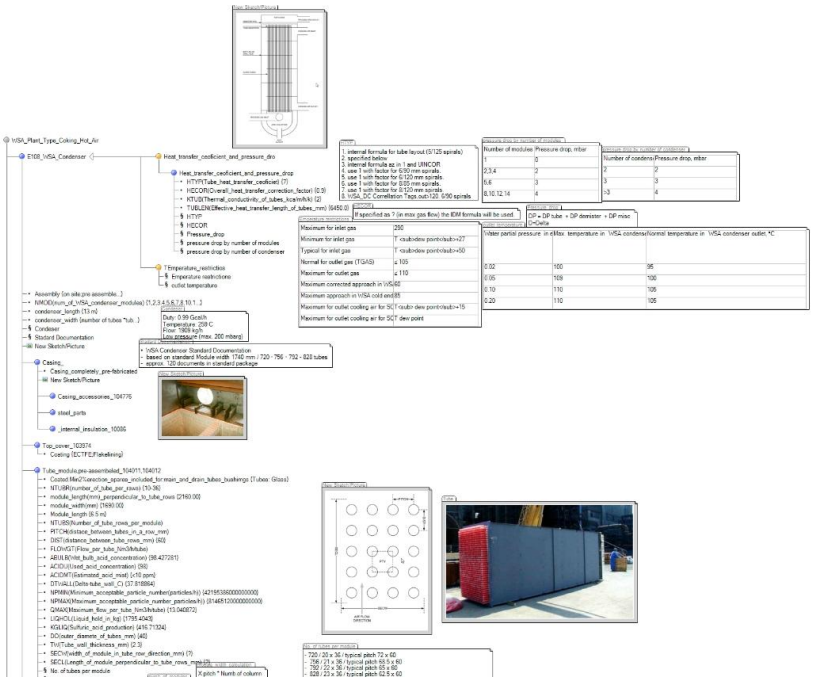
7,07106781	3,60555128	5
fa	fd	fh
7,21110255	4,12310563	5,38516481

0,67148454

Ongoing Project at the company

Phase 1: Identify relevant product features from configuration system

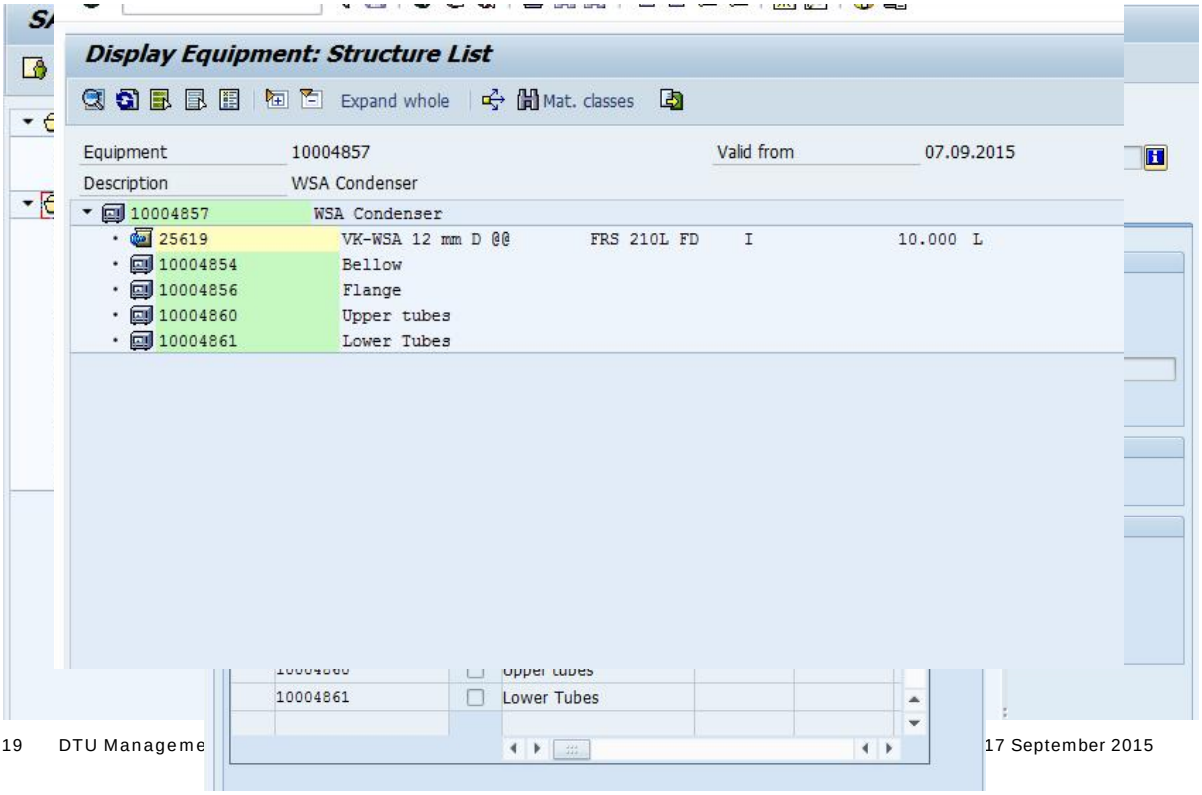
Making a Product Variant Master (PVM) and the available variants from the configuration system



Ongoing Project at the company

Phase 2: Retrieve specifications on previous designed products from ERP / PLM system

Phase 3: Retrieve features from product files and determining the values



Ongoing Project at the company

To be continued


Thank you for listening