Technical University of Denmark

Measuring process and knowledge consistency

A necessary step before implementing configuration systems

Edwards, Kasper; Ladeby, Klaes Rohde; Haug, Anders

Published in:
Innovative Processes and Products for Mass Customization

Publication date:
2007

Document Version
Early version, also known as pre-print

Measuring process and organisational consistency – A necessary step before implementing configuration systems

Author(s): Kasper Edwards, Klaes Ladeby Jensen and Anders Haug,

Department of Manufacturing Engineering and Management, Technical University of Denmark, Build. 423, 2800 Lyngby, Denmark. (email: Edwards@ipl.dtu.dk)

Abstract

When implementing configuration systems, knowledge about products and processes are documented and replicated in the configuration system. This practice assumes that products are specified consistently i.e. on the same rule base and likewise for processes.

However, consistency cannot be taken for granted; rather the contrary, and attempting to implement a configuration system may easily ignite a political battle. This is because stakes are high in the sense that the rules and processes chosen may only reflect one part of the practice, ignoring a majority of the employees.

To avoid this situation, this paper presents a methodology for measuring product and process consistency prior to implementing a configuration system. The methodology consists of two parts: 1) measuring knowledge consistency and 2) measuring process consistency. Knowledge consistency is measured by developing a questionnaire with a 5 point Liker scale and a corresponding scoring system. Process consistency is measured by using a first-person drawing tool with the respondent in the centre. Respondents sketch the sequence of steps and people they contact when configuring a product.

The methodology is tested in one company, and the paper presents and discusses these results.

Keywords

Configuration, knowledge, process, consistency, measurement

1 Introduction

Product configuration systems are IT-systems that support the task of specifying a product. The product specification task is concerned with transforming the customers' wishes into a product.

While the product specification process may be very different from firm to firm the degree of engineering involved determine how much the may change. Engineering companies who offer tailor made products and solutions to their customers will have a very varying specification process. Whereas a simple and not customizable goods will not allow changes to the specification as it's a simple selection between products.

In this paper we focus on specification processes with a degree of engineering i.e. it is possible to make changes to the structure or function of the product during specification. When the specification process contain a more or less pronounced element of engineering it becomes idiosyncratic as the engineer uses his knowledge about product, process and the customers need to specify the product.

In the PETO project (Edwards, Hvam, Pedersen, Møldrup, & Møller, 2005) it was observed that half of the firms offered product with a significant engineering content. These firms were in the process or had already implemented product configuration systems. Although not the focus of the PETO project the interviews hinted significant concerns with the future specification process. And this to a degree that some respondents had already before implementation developed counter strategies to the configuration system supported specification process.

These observations hinted that moving from a specification process which is often idiosyncratic to a structured configuration system may not be simple. A configuration system assumes both a consistent product model with rigid rules governing which components and features are allowed together and map to each other. A configuration system also assumes a process or work flow ensuring that features and components are added based on previous valid solutions.

A configuration system will force engineers and employees in general to follow the workflow structured by the configuration system. Implementing configuration systems before having established consensus about the quotation process and product structure may induce reluctance to change or the observed counter strategies. The engineers, being intelligent, will naturally realize this in early stages of the implementation process and fight to have their idiosyncratic perception of the product structure and specification process reflected in the system. This a completely natural response to a possible change scenario which triggers a political process of gaining control over the configuration system, project and the product and processes.

This prompted us to formulate the following research question: "Is it possible to test how idiosyncratic process and product knowledge is, without, without triggering a political battle?"

We answer the research question by proposing that process and knowledge consistency can be measured and thereby provide a measure of the idiosyncrasy level in the organization. If consistency is very low it is advised to embark on an organization development project to establish consensus followed by a product configuration project. We choose to focus on the product specification process in firms who deliver products with an engineering content.

2 Process Consistency

The basis for each and every company is the knowledge of its employees and the organisation of activities. Simply put organisation is about who does what and when. For engineering companies or indeed all companies which produce to order, the customer triggers a number of processes in the firm. If all goes well these processes end up with delivering the customers desired product.

A process is a sequence of steps which has to be undertaken and completed in order to reach a specific result. In this paper we define process consistency as the ability of an organisation to complete the same sequence of steps when undertaking similar tasks, independent of the person. This definition assumes that business processes are undertaken by an organisation and not individuals with freedom of methodological freedom.

Process consistency is essential to achieve consistent results in an efficient manner. Imagine the McDonalds chain of restaurants allowing the kitchen staff to use different processes, this wound defeat the point of the brand name, which is associated with a specific flavour regardless of location in the world. The essence of Lean manufacturing is detailed understanding of the processes and adherence to repeat the process in the same way each and every time.

Engineering firms, however, are not McDonalds and not mass producers. Engineering firms are characterised by their ability to engineer their product to the customers' specific need. It makes little sense to build the same type of bridge in two completely different locations with different length etc. Engineering firms must take into account the specific situation and design a bridge (or whatever product/construction) to fit the situation.

While this may begin to sound as an argument in favour of not having an organisation it is far from. Engineering firms as well as their more mass producing brethren must have stable processes ensuring quality, consistency and productivity. However, engineering firms must allow a larger degree of freedom in their processes. Building two bridges in two locations where only the ground differs will require different expertise in the project. If the ground is hard rock one type of foundation can be used, and of the ground is soft a completely different type of foundation must be used. Still most of the remaining structure remains the same. In this example the process of designing a bridge require different expertise for the foundation as such the processes are different but the main structure of the process remain largely the same.

Naturally engineering firms may encounter projects which disrupt the organisation although these are not the focus of this paper. Rather the focus is one of consistency when encountering similar problems within an organisation.

What we seek is a tool or technique which allows us the capture the process of a specific product across a group of employees whom may perform this function. The tool or technique should measure the individual processes and allow us to state if they are idiosyncratic or consistent. The latter part is a simple matter of comparing and identify the level of differences.

A number of tools exist for mapping processes such as Values Stream Mapping (VSM), Business Process Modelling Notation (BPMN) and IDEF0 all of which has their advantages and disadvantages. However common to all is that they take a 3rd person view of the process and map a general view of the process. VSM takes this to the extreme as it is a part of the actual change process where employees formulate current state and a future state together. This forces collaboration and is often an eye-opener as to the consequence of one process to other processes.

Here the explicit purpose is to uncover differences in processes before initiating a change in the organisation. For this reason the process map must be first person and egocentric to the employee in question and yet possible to compare with other maps.

To accomplish this we propose a technique where each employee, which is part of the process, is simply asked to map out the process on a process outline sheet (see Figure 1). The process outline sheet places the person in centre of the diagram allowing the respondent to view the process from his perspective. The various functions and perhaps customer is placed in function circles around the centre. The task is then to draw arrows from between functions as the respondents perceive them and number the arrows. To ensure the respondents actually draw the same process i.e. a process for a specific product, a specific request for quote is provided.

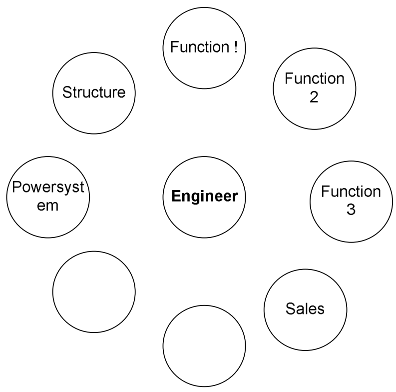

Figure 1: The process outline sheet where respondents draw the activity sequence.

Analysing the results is a simple comparison of the process outline sheets. It seems overkill to develop an advanced method for calculating differences as it is the qualitative understanding of differences that are interesting.

If large differences can be observed it is necessary to embark on an organisation development project with the purpose of uncovering "how do we specify our products?". Using Leans' kaizen event methodology would appear to be a good approach although BPMN may be a better mapping tool as this will allow a more detailed description of the process.

3 Knowledge consistency

The premise for measuring knowledge consistency is that employees essentially should be able to provide similar answers to identical questions. This is based on the assumption that regardless of which employee a customer approaches, they should reach similar specifications. If employee's have very different knowledge about the products they will propose different solutions to the customer some of which may not even be suited for the customers' application. From a company perspective this is far from an ideal situation in the sense that personal persuasion rather than performance criteria determine the solution. Such differences in perception may result in very different prices and can be the deciding difference between getting or not getting an order.

We define knowledge consistency as the rate of identical responses to a question. Within the process of specifying a product it this knowledge is about product function, structure and their interrelation.

There are several ways to go about trying to measure knowledge consistency and the first which springs to mind is a regular exam type of questionnaire and rating. However, such an approach suffers from a major weakness as it assumes that all questions a priori have a right answer. This assumption may be true for firms with standardized products but less so for firms with an engineering component in the specification process.

The engineering component is actual product development where new combinations of application, function and structure is created. It is often the case that such new combinations are reused and over time becomes a standard product.

Consequently the measuring methodology cannot assume a right or wrong answer but must focus on consistency across respondents. Naturally this assumes that the respondents have similar job functions. By measuring knowledge consistency we are interested in identifying and quantifying different opinions.

We propose a 5-point Likert scale (Likert, 1932) questionnaire as the tool for recording respondents' answers. Likert type questionnaires are indeed easy to use for the respondent, which contribute to our choice. Likert type questionnaires allow a question to be stated, for which a number of alternative answers are presented. This will allow respondents to simply answer “Agree” to “Don't agree” on a 5-point scale to the presented answers. There are some differences in the literature of whether to use 3, 4, 5, 6, 7 or more responses (Clason & Dormody, 1994). Here a negative number is chosen to allow an indifferent response. A 5 response alternatives were chosen over 3 to allow a level of in-between. 7 or more response alternatives were not used in favour of simplicity.

The questions and alternative answers in the questionnaire represent the knowledge we seek to identify as consistent or not. The knowledge expressed as questions must be related to the practice which unfolds in the department on a daily basis and thus is assumed to be consistent among the employee group. The questions are perhaps more like meta-questions in the sense that they form a frame within the respondent can agree or not to a number of possible responses. An example meta-question and response would be:

Choosing O-ring rubber type XYZ result in the following:

Response	**Agree**	**Don't agree**
Sufficient sealing for sub-zero temperature		
Can absorb vibration of X distance		

Figure 2: Example of a meta-question with matching responses

The example question is inspired by the Challenger Space Shuttle disaster in January 1986 where O-rings in the booster rockets failed to provide proper sealing. This allowed super heated gasses to escape thereby burning a hole in the main fuel tank causing a fatal explosion.

3.1 Calculating consistency

Contrary to our initial thoughts it is not trivial and no standard method exist to measure consistency from the completed questionnaires. This prompted an effort to create a calculation method that can use Likert type data and generate simple numbers allowing aggregation and conclusions to be drawn.

Essentially we are interested in finding out how consistent a group of people respond to a given question. Differences between groups is not of interest as it is assumed from the onset that consistency exist e.g. people performing the same job. Further we don't care if respondents answer objectively right or wrong but only how the responses are grouped. This means it is not possible to assign a score based on a master questionnaire with correct questions. Rather consistency must be calculated based on how similar the answers are.

The calculation is further problematic as the population to be examined is small and expected to be less than 20. The PETO project interviewed 12 companies of varying sizes and event the largest firms with more than 2000 employees had less than 20 people in central positions in the specification process. Consequently a statistical approach cannot be expected to yield good results and a custom scoring system is a better solution.

Analysing the responses differs from traditional questionnaire analysis as each questionnaire is not treated as an entity. The point of comparison is the individual responses to a question in the questionnaire allowing a comparison of knowledge consistency. For this type of analysis there are no standard statistical procedures as we are measuring differences in individual responses.

For this very reason we propose a scoring system which seeks to measure relative differences between each employees' response. The scoring system must favour similar answers and place a penalty on increasing different answers. This is facilitated by the Likert scale where the 5-point difference provides a measure of the difference between responses.

The scoring system does so by first aggregating the responses into a single matrix, showing how many respondents agreed or what not to the specific answers. Next the score is calculated based on the distance between answers and the highest score is reached if all answers to a question is the identical, giving a score of (n*n-1). Depending on distance between responses as defined by the 5-point Likert scale, a distance factor is multiplied.

Naming the fields in the Liker scale as A to E as illustrated in the following table:

Agree				**Don't**
A	B	C	D	E

Table 1: Naming convention of the fields.

Thus we propose the distance factors as: A-A: 1; A-B: 0,5; A-C: 0; A-D: -0,5 and A-E: -1.

This factor's place a significant penalty on large differences and favour close grouping of answers. The factors are inspired from the bell shaped normal distribution where the bell shaped curve must be within three fields in the Likert scale e.g. position A, B and C. The underlying assumption is that if the answers follow a normal distribution, then knowledge is consistent. A normal distribution test would have been preferred but due to the low number of expected responses the scoring system was created. The scoring system is exemplified in Table 2.

Nr.	Agree				Don't	Score
1	2	0	0	0	0	**2**
2	1	1	0	0	0	**1**
3	1	0	1	0	0	**0**
4	1	0	0	1	0	**-1**
5	1	0	0	0	1	**-2**

Table 2: Scoring calculation for two respondents, showing differences in score as the two respondents increasingly choose different replies.

In practical use the system is easily employed using basic spread sheet and calculating score for each position in the Likert-scale. As an example we calculate the score for position A, with number of responses denoted as a, b, c, d, e referring to the fields in a row (see Table 1)

ScorePosition A= a*(a-1)+0,5*(a*b)+0*(a*c).-0,5 *(a*d)-1*(a*e), Similar calculations are done for all fields and trivial to complete.

3.2 Analysing Results

A score of more than 50% indicate that replies are grouped around three points indicating consistency. As consistency is reached one may press ahead and implement product configuration and regardless for the information source used it can be expected that derived rules will match expectations of other employees.

The scoring calculation places a penalty on differences in consistency and a score of less the 50% indicate that there replies are not consistent for the specific reply across respondents. This situation will require a development project where employees establish a common understanding of product application, function and structure.

A negative score indicate polarized responses where respondents are grouped in opposite ends of the scale. The two groups are internally consistent but significant differences exist across groups. This situation typically arise when two departments are geographically disperse or when the groups have historically been working with different products. In the latter case underlying assumptions and product understanding is carried over from one development context to a new one. This is a dangerous situation which may escalate to a conflict over time as the two groups develop a biased understanding of the other group based on the results of their work. One way to resolve such a finding is to have a product development conference where the two groups discuss the products. The purpose of the conference is to make explicit the underlying and often tacit assumptions which trigger polarized responses.

4 Empirical Test

The measuring schemes were tested in a Danish firm, "Furnatics", who produces furnace systems. Furnace systems are engineered products and require extensive design and calculation before a plant can be build or even a tender delivered. Furnatics is a rather old firm which has existed in more than half a century and is currently experiencing a growth period with a 2004 turnover approaching 100 million Euros. The firm has 400 employees and is organised two departments which are in different parts of the country although they both carry out much of the same tasks. Orders sizes range from 9 to 50 million Euros consisting of a feeding system, furnace grate, transport waste product from the furnace, a boiler, flue gas system. The dimensions of a furnace are calculated from the volume and type of material to be burned in the furnace.

A critical process in Furnatics is the quotation process which deals with requests for tender and quotes. The quotation process is a funnel where incoming requests for tenders and quotes are screened as to the probability of winning the order. About 30-50 requests are selected for an initial response, which is a very rough specification of the requested product and a price estimate. Often the customer returns with change requests and suggestions which results in a new rough specification and price estimate. This process may continue back and forth a number of times. The quotation process require substantial resources and Furnatics submits on average 12 detailed tenders/quotes a year of which 3-4 result in actual orders being placed.

Producing a detailed tender/quote is a complex task which is vulnerable in two aspects: 1) price, if the price is too high the customer will not accept the tender and if the price is too low Furnatics will loose money on the project. 2) Specifications, if specifications are wrong the furnace may not deliver the specified energy output, causing the customer to loose money and in turn Furnatics will be sued for breach of contract.

Furnatics is therefore considering implementing a configuration system to support the tender and specification process. Furnatics allowed two master thesis students to implement a prototype configuration system and to measure Furnatics knowledge and process consistency to estimate configuration readiness. Two departments were selected for the tests: 1) sales and 2) quotation. The sales department with 3 employees is responsible for customer contact, marketing and delivering estimated tender. The quotation department with 6 employees is responsible for producing detailed tender based on information from the individual domain experts.

4.1 Measuring Process Consistency

The nine respondents from both sales and quotation department were given identical copies of a previously made tender and asked to map out the process for producing it. The process outline sheets were subsequently rearranged to place the individual process steps in the same location for all respondents to allow visual comparison.

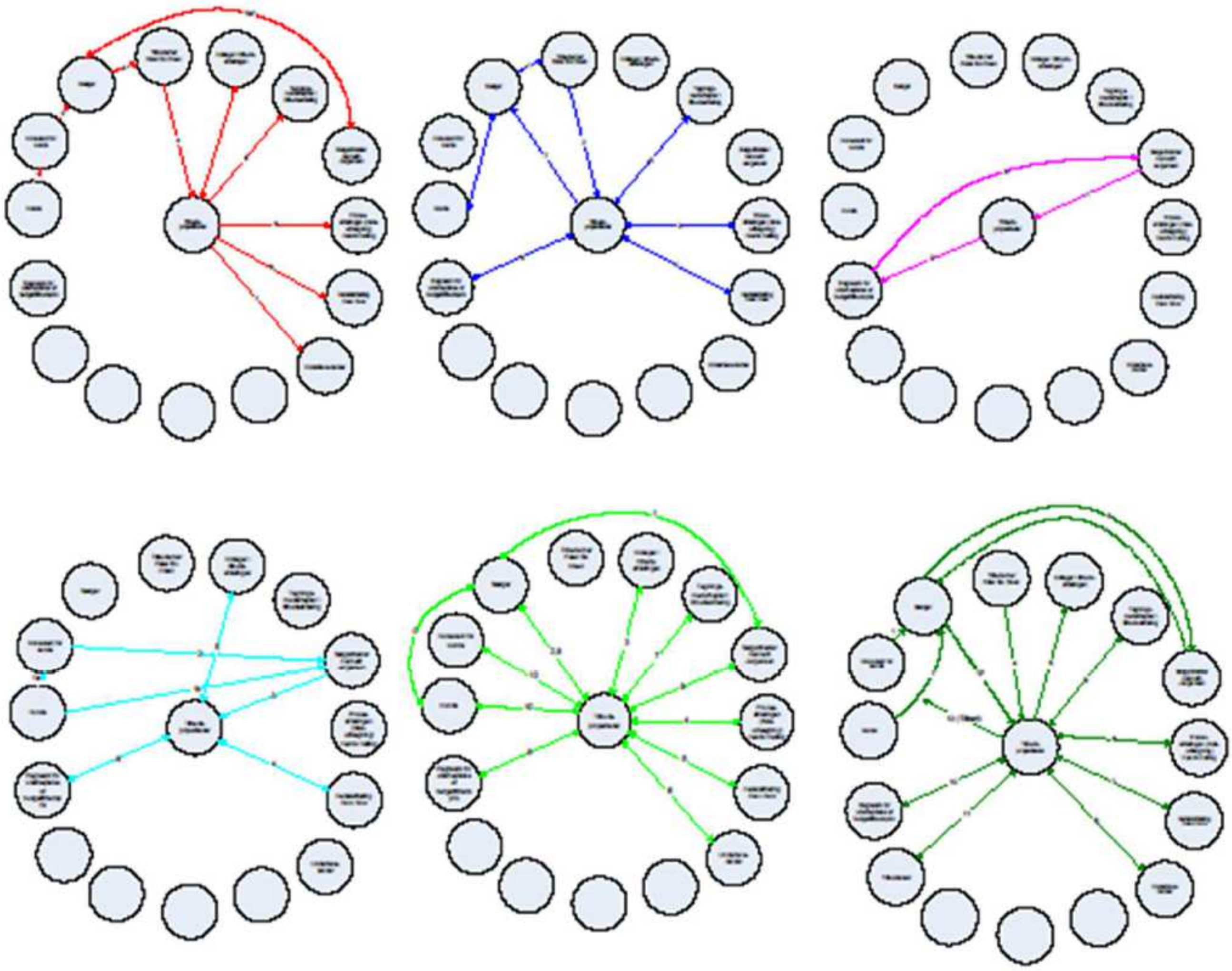

Table 3: Process outline sheets from the quotation department.

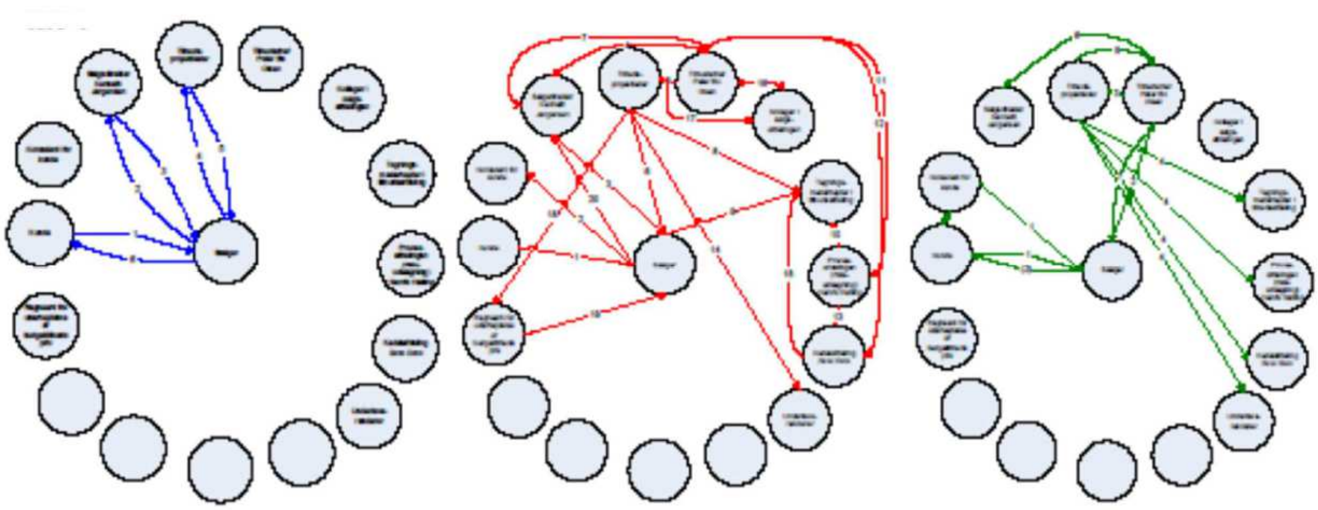

Figure 3: Process outline sheets from the Sales Department.

Inspection of the process diagrams reveals significant differences and no consistent process across both quotation and sales department. Process starting points and the sequence differ across all responds.

It is evident that the process in these two departments is not consistent. Such inconsistency is not compatible with implementing a configuration system without discussing the proper process.

4.2 Measuring Knowledge Consistency

Knowledge consistency was measured using the proposed methodology and organized as 9 technical meta-questions each with a number of responses to which the respondent could mark from “Agree” to “Don’t agree”. The meta-questions were developed from interviewing engineers and an analysis of the product structure.

What are the advantages of a pusher feeder compared to a grate feeder?

Response	**Agree**				**Disagree**	***Score***
No advantage	5	1	0	0	0	*83*
A more stable feed	0	2	1	0	3	*13*
Less sensitive to material types	0	0	4	0	2	*47*
Number of customer references	0	0	0	2	4	*73*
Pusher is preferred by customers	4	2	0	0	0	*73*
Use of pusher is a management decision	3	0	0	1	2	*-17*
We offer same feeder as used in earlier sales to the same customer	0	0	5	0	1	*67*
Construction considerations	0	1	4	0	1	*50*

Table 4: Snippet of the completed response charts and score.

4.2.1 Results

Results from the knowledge consistency test in the two departments are shown in

Figure 4 and Figure 5. Results from both departments show consistency in 19 out of 47 questions i.e. 40%.

It is interesting but coincidental that both departments reach exactly same score i.e. 40% as the differences occur in the responses. However, this is staggering inconsistent when considering that these departments has few people, 3 and 6 respectively, performing these functions. The sales department is in the same geographical location and it must be concluded that little or no knowledge exchange exists in this group

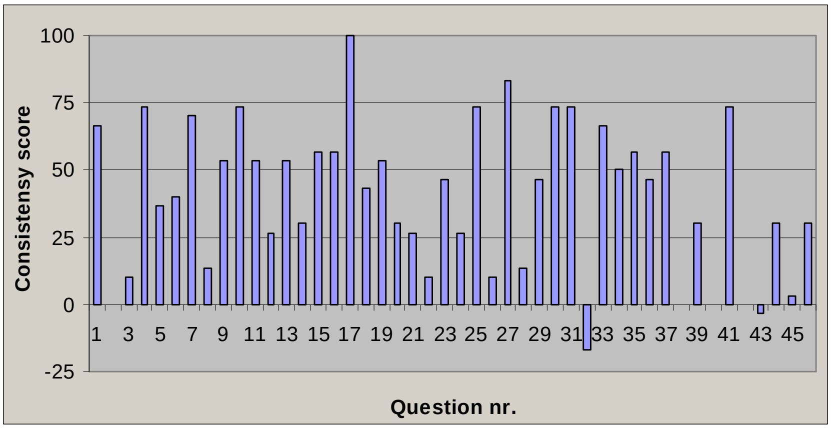

Figure 4: Quotation department knowledge consistency.

The quotation department is geographically dispersed with a two groups placed in each end of the country. While this may account for some lack of consistency, it appears that more polarization should have been evident. Where in fact polarization is only present in two responses and even here it is not extreme. The majority of the responses illustrate an almost random distribution of responses. As such the only possible conclusion would be that the quotation department does not share knowledge or practice. This suggests that the quotation department is in dire need of a development. Indeed such lack of consistency must induce very varying solutions and a general problem of reaching a consistent price.

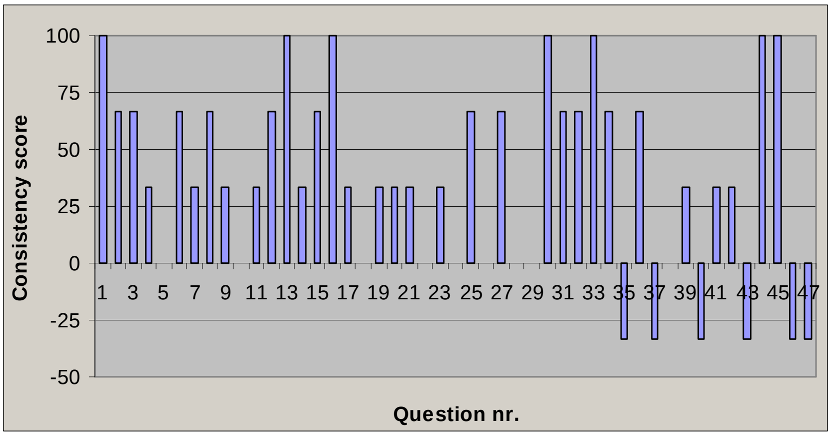

Figure 5: Sales department knowledge consistency.

5 Discussion and Conclusion

Proposing a new type of measurement is always a recipe for disaster in the sense that a valid question remains: Why not using what is already there? This section is dedicated to this very question.

The overall aim of these two tests was to develop a tool which was easy to use and allowed a test of process and knowledge consistency without triggering a political battle. In practical use this tool does just that. It proved very easy to collect data mainly because it is little time consuming for respondents to complete the questionnaire and process outline sheet i.e. less than 45 minutes.

The results were further conductive for the process of developing consistency among the sales and quotation staff. The results were used in a series of workshops intended to develop a common understanding and thereby consistency. The charts were presented for the respondents at a workshop which allowed then to see painstaking clear their individual differences. This sparked a very fruit full discussion about why and how they performed their jobs. While this may sound like a Kaizen event it is far from as focus here is on the underlying product knowledge and its inherent logic.

The lack of consistency in the processes is a consequence of inconsistent product knowledge and as only one engineer in a project can see the whole picture no one questions a request for calculation. For this reason the product knowledge must be understood first and then a new quotation process can be developed.

The process outline sheet was developed with the specific purpose of illustrating a first person view and did so well. When presented in a slide show differences was obvious and could not be refuted as it was the individual process charts.

It would have been preferred to have employed a more sophisticated mathematical and statistical model and indeed many avenues have been exhausted. A number of problems exist making it difficult to use statistical models: 1) We are comparing individual responses and not trying to profile the respondents. 2) There are no correct replies and it is not possible to derive expected results. 3) The population is small and even for large companies the population will be low i.e. <20 people. Thus statistical significance cannot be reached.

Despite these obvious weaknesses the consistency score was shown to work well and deliver intuitive results expressing whether the responses were grouped, scattered or polarized. It must be emphasized that the purpose was not to provide a solid mathematical/statistical method. Rather the purpose was to develop an easy to use tool which can provide a graphical illustration of the knowledge responses to be used in the process of reaching consistency – which it did surprisingly well.

References

Clason, D. L. & Dormody, T. J. (1994). Analyzing Data Measured by Individual Likert-Type Items. *Journal of Agricultural Education, 35*.

Edwards, K., Hvam, L., Pedersen, J. L., Møldrup, M., & Møller, N. (2005). *Udvikling og implementering af konfigureringssystemer: Økonomi, teknologi og organisation*.

Likert, R. (1932). A Technique for the Measurement of Attitudes. *Archives of Psychology, 140*.

6 Appendix

Complete scoring table for the quotation department:

Nr.	Agree			Disagree		Score
1	1	4	1	0	0	**20**
2	0	0	0	0	0	**0**
3	3	1	1	0	1	**3**
4	0	2	4	0	0	**22**
5	0	1	2	2	1	**11**
6	1	3	1	1	0	**12**
7	3	3	0	0	0	**21**
8	2	2	1	0	1	**4**
9	3	2	1	0	0	**16**
10	2	4	0	0	0	**22**
11	0	3	2	1	0	**16**
12	0	1	2	1	2	**8**
13	0	0	3	2	1	**16**
14	0	1	1	2	2	**9**
15	2	3	1	0	0	**17**
16	0	0	4	1	1	**17**
17	6	0	0	0	0	**30**
18	2	1	3	0	0	**13**
19	0	3	2	1	0	**16**
20	0	1	1	2	2	**9**
21	3	1	1	1	0	**8**
22	1	2	1	1	1	**3**
23	2	0	4	0	0	**14**
24	0	1	2	1	2	**8**
25	4	2	0	0	0	**22**
26	3	1	1	0	1	**3**
27	5	1	0	0	0	**25**
28	0	2	1	0	3	**4**
29	0	0	4	0	2	**14**
30	0	0	0	2	4	**22**
31	4	2	0	0	0	**22**
32	3	0	0	1	2	**-5**
33	0	0	5	0	1	**20**
34	0	1	4	0	1	**15**
35	4	1	1	0	0	**17**
37	0	0	2	0	4	**14**
38	1	3	2	0	0	**17**
39	2	1	1	1	1	**0**
40	0	2	2	1	1	**9**
41	0	0	0	0	0	**0**
42	4	2	0	0	0	**22**
43	0	0	0	0	0	**0**
44	1	2	0	1	2	**-1**
45	2	0	3	1	0	**9**
46	1	1	2	0	2	**1**
47	2	2	1	1	0	**9**

Complete scoring table for the sales department:

Nr.	Agree			Disagree		Score
1			3			**6**
2				1	2	**4**
3	2	1				**4**
4	1	1	1			**2**
5	1	1		1		**0**
6	2	1				**4**
7	1	1	1			**2**
8		1	2			**4**
9	2		1			**2**
10	1	1		1		**0**
11		2		1		**2**
12				1	2	**4**
13					3	**6**
14		1	1	1		**2**
15	2	1				**4**
16			3			**6**
17	2		1			**2**
18						**0**
19	1	1	1			**2**
20	1	1	1			**2**
21			1		2	**2**
22		1	1		1	**0**
23			1	1	1	**2**
24		1	1		1	**0**
25	1	2				**4**
26						**0**
27	2	1				**4**
28						**0**
29						**0**
30					3	**6**
31	2	1				**4**
32	2	1				**4**
33			3			**6**
34		1	2			**4**
35	1	1			1	**-2**
36				1	2	**4**
37	1		1		1	**-2**
38		1	1		1	**0**
39	1		2			**2**
40	1		1		1	**-2**
41	1		2			**2**
42	2		1			**2**
43	1		1		1	**-2**
44					3	**6**
45					3	**6**
46	1	1			1	**-2**
47	1		1		1	**-2**