The Adoption of Production Concepts: An Empirical Review

Groningen, august 2006

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Abstract

Scientists have developed the Agile Manufacturing and Quick Response Manufacturing concept as an answer to increasing competition that arises from globalization. These new production concepts find their origin in the Lean Manufacturing concept, but are developed for companies deliver more customization and are therefore exposed to higher variety. This study investigates how these new concepts have adopted in practice. The focus is the relationship between customization and the use of practices. For customization production systems (ETO, MTO, ATO and MTS) were chosen that classify different degrees of customization. To measure the use of the production concepts, management practices were defined and their use in practice was measured. Additional influences that could disturb the findings were identified as current and former strategy, size and innovativeness. These factors were included in the investigation. Data was gathered from practitioners with an Internet based survey. And the results were analyzed with ANOVA tests. The results showed that there is still a negative relationship between the use of practices and customization. However, the ETO production system breaks this trend. The analysis of strategy suggests that the differences will disappear in the future, and companies that are innovative are leading the way.

1. Introduction

Globalization is a hot topic, both in theory and in practice. The improving infrastructures of sea, air, road transportation and information technology provide opportunities for companies to enter new markets across the globe. The turn side of globalization is that companies experience increasing competition, both in their domestic market, and foreign markets. The Japanese set the tone by competing on cost, and delivering high value for money while embracing the Lean concept. Now the entrance of low wage countries, like China, India and Eastern Europe, on the global market adds to the competition. Therefore North America and Western Europe are now embracing the production concepts to optimize their operations.

The outlook is grim for these regions if companies try to compete on cost. Therefore scientists have developed the Agile Manufacturing and Quick Response Manufacturing (QRM) concepts as extensions of the Lean concept over the past decade. These concepts increase value for money by for the customer by delivering increased customization or shorter lead-times.

The relevance of theoretical developments is validated by their adoption in practice. Therefore it is interesting to see if these concepts got a strong foothold among practitioners. White and Prybutok (2001) have conducted a valuable study in this area. Their findings were that companies that deal with a high degree of product variety[1] make less use of the Lean concept compared to companies with high levels of standardization. However their investigation is nearly a decade old, and the findings exclude companies that produced in batches. However, batch production is a significant part of the continuum from standard to customized product and White and Prybutok (2001) left a gap in their findings. The aim of this research is to discover how the developments of the Lean concept have been adopted in practice, without gaps in the continuum of customization.

In the next chapter a brief review will be done to provide information on the research that has been done in this area. In the second part of the chapter the production concepts and production systems will be defined, and the practices that White and Prybutok (2001) used will be update to be generic for the Lean, Agile and QRM concepts. At the end of chapter two the hypothesis will be posed, and additional influences on the relationship between production system and use of practices will be discussed. Chapter three will discuss the methodology used for gathering information, and the fourth chapter will discuss the data that was received. Subsequently the analysis will be done that will provide an answer to the hypothesis that were posed in the fifth chapter. Finally, the differences that have been found in the analyses will be discussed, and explanations will be given about their nature.

[1] Customization leads to product variety automatically. Since products are made for specific for each customer.

2. Literature Review and Hypotheses

Lean concept implementation studies have been conducted frequently and can be divided into two streams. The first stream focuses on the relationship between lean implementation and performance of a company (Cua, McKone and Schroeder, 2001; Shah and Ward, 2003). The other stream in literature examines the factors that influence the implementation (Nakamura 1998; White 1999 & 2001). This study extends this last research area. The study by White and Prybutok (2001) will serve as the starting point for this research as their distinction is directly linked to variety. According to Hayes and Wheelwright (1976 I + II) the product structure and process structure only exist in distinct combinations (Figure 1).

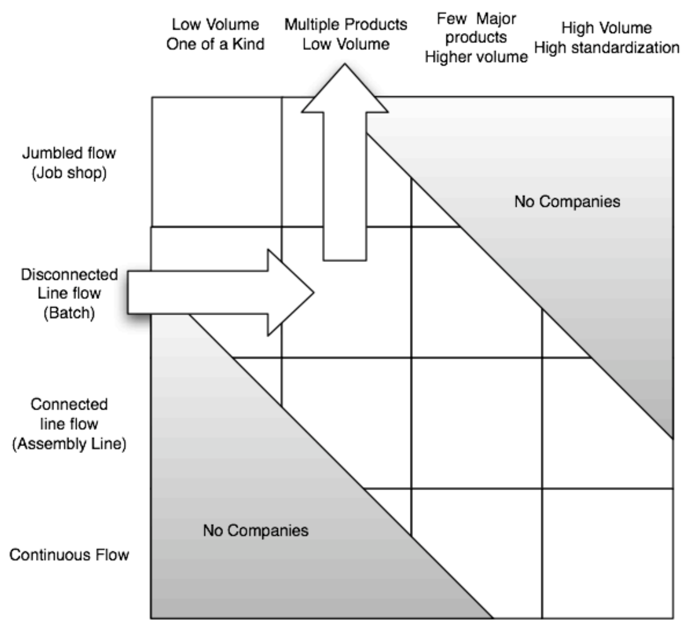


Figure 1: Product Process Matrix (Hayes and Wheelwright, 1979 I & II)

Practices

The Lean Manufacturing concept is a combination of seven principles: simplification, cleanliness, visibility, cycle time, agility, variability reduction and measurement that are applied in the production process. Different techniques have been developed that examine the production system on wastes, inefficiencies, and eliminate them (Slack, 2001; Nicholas, 1998). These techniques can be categorized in to sets that are similar in area of application. These sets of similar techniques will be referred too as practices

(Figure 2). The Agile Manufacturing concept incorporates the Lean Manufacturing principles, but agility is then most important (Poesche, 2002). QRM has the same structure as the Lean and Agile concepts, but Suri (1998) identified an additional source of waste, lead-time/speed and developed techniques as Polca, and the lead-time advocate. Therefore, the techniques for the Agile and QRM concepts can be classified into the same practices as the Lean concept.

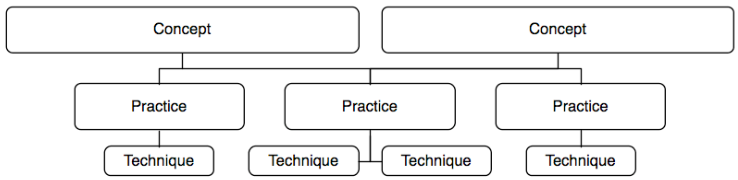


Figure 2: Structure of the Lean concept

In their studies White and colleagues (White et al., 1999; White and Prybutok, 2001) used a set of 10 Lean[2] practice: quality circles, total quality control, focused factory, total productive maintenance, reduced setup times, group technology, uniform workload, multifunctional employees, Kanban and JIT purchasing. This set of practices is in line with most other researches although some vary in level of analysis. For instance Cua et al. (2001) place TPM and TQM at the same level as Lean manufacturing and recognize more practices. Others use about the same practices as White et al. but give them slightly different names; Nakamura (1999) uses specific equipment layout configurations for focused factory. Another important distinction that is often made (Siruparavastu et al. 1997; Nicholas, 1998) is the term work cell concept or cellular manufacturing. This is actually a special kind of focused factory where every operation on a (sub)assembly is performed in a single cell.

For this research the practices that were developed by White et al. (1999) will be used. However updates will be applied to the terms Kanban and JIT purchasing. Development in materials handling systems have led to other pull and hybrid production planning system such as Polca (Suri, 1998), ConWIP and workload control (WLC) (Nicholas, 1998). Therefore the practice Kanban is renamed pull system. This is in line with the terminology used by Cua et al. (2001) Shah et al. (2003) and Nakamura et al. (1999). JIT Purchasing has grown in its scope. It has extended from the first tier supplier to the entire

[2] White & Prybutok (2001) use the term JIT practice

supply chain (Nicholas, 1998). Therefore the term supply chain management will be used.

Production system

White and Prybutok (2001) made a classification of the production system based on repetitiveness. They classified job shop as non-repetitive production systems and continuous flow/assembly line as repetitive production systems and left batch production systems out.

> *"Since batch does not provide a clear distinction for differentiating from either of the ends, it is not included as a classification of production processes in this study."*
>
> -White and Prybutok (2001: p. 114)

The fact that this process structure was left out means there is a gap on the product structure[3] since these can only consist in distinct combinations (Figure 1, Hayes and Wheelwright, 1979 I & II). To avoid this gap in this research another distinction had to be made, one that was mutual exclusive over the continuum from standard product to a one of a kind production.

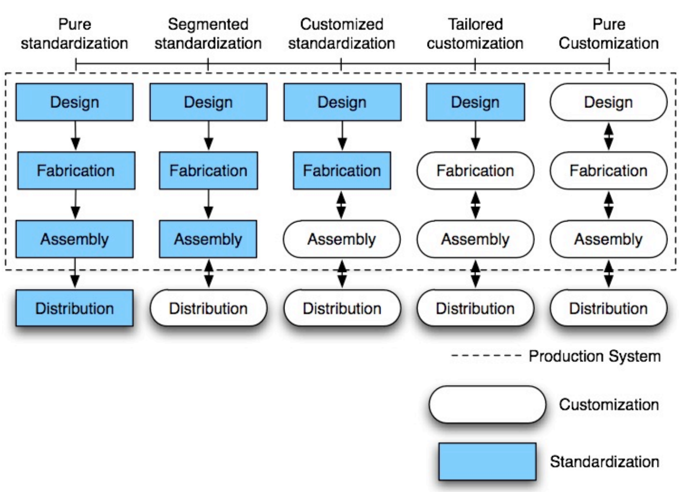


Figure 3: Customization Strategies by Lampel and Mintzberg

[3] Product structure is the volume, variety mix that is produced.

Lampel and Mintzberg (1996) developed customization strategies based on the production stage where the product is made specific for an individual order (Figure 3). Pure customization is equal to one of a kind production and can exist in a job shop process structure. Pure standardization and segmented standardization have no customization in the production process. This implies high volumes and therefore continuous flow.

Laddha and Suresh (2005) linked the customization strategies of Lampel and Mintzberg (1996) to the production system. The different production systems they recognize are Engineer-to-Order (ETO), Make-to-Order (MTO), Assembly-to-Order (ATO) en Make-to-Stock (MTS). When the distinction that White and Prybutok (2001) use is compared to Laddha and Suresh (2005) the conclusion can be drawn that the MTO production system is left out (Hayes and Wheelwright, 1979 I & II) (Figure 4).

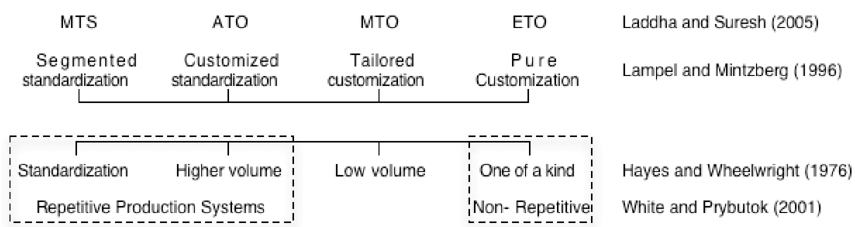


Figure 4: Approaches for Customization[4]

Research Questions

The aim of this study was too discover how the developments of Agile Manufacturing and QRM have been adopted in practice. This aim was split into two questions that will be answered in this study. First, is there a difference in the use of practices between different degrees of customization? We used the number of practices that are in use too measure these differences. In the remainder of this section we will formulate the hypotheses for this question. Second, what is difference between the practices used in different production systems? To answer this question a graphical analysis will be conducted. Chapter six will report about this analysis.

[4] Pure customization (Lampel and Mintzberg, 1996) is left out, as the difference with segmented customization is outside the production system (figure 2). The classification of Hayes and Wheelwright has been mirrored from Figure 1.

Hypotheses

The Lean concept is based on standardization principles and tries to reduce variety in products and processes (Nicholas, 1998). Therefore it is suitable for production systems with low variety and relative stable demand. The Agile concept is an extension of the Lean concept that increases the flexibility of a production system. So the Lean concept is suitable for the left site of the customization continuum, whereas Agile can be applied at the right side. This implies that there should be no difference between the use of practices for the different production systems. This assumption will be hypothesized as:

H_1: There is no difference in the mean number of practices in use between the four different production systems.

The Influence of strategy

The Quick Response Manufacturing (QRM) concept has been developed for companies that deliver more custom products, and want to distinguish themselves on speed and dependability (Suri, 1998). So with the cost oriented approach of Lean, the flexibility approach of Agile (Vorkurka and Vliedner, 1998; Hines et al., 2004) and the speed and dependability of QRM concepts have been developed for four strategic orientations. Quality is for all concepts a prerequisite (Nicholas, 1998: Hines et al. 2004; Suri 1998). This implies that strategy has no influence on the relationship between the production system and the use of practices. This assumption will be tested in:

H_2: The Strategic orientation of a firm has no influence on the relationship between production system and the use of practices.

To test H_2 appropriate strategies need to be found that cover the theoretical covered strategies. In literature the strategies of Porter (Schilling, 2005), Treacy and Wiersema (1983) and Ferdows and de Meyer (1990) can be recognized. The strategies of Ferdows and de Meyer (1990) are the considered the most operational (Tsao and Wang, 2005), and most used (Vorkurka and Fliedner, 1998; Tsao and Wang, 2005). Therefore, the strategies of Ferdows and de Meyer (1990) will be used for this investigation. They recognized four strategies: cost, quality, dependability and flexibility. Speed will be added as the leading objective for QRM (Suri, 1998).

During the introduction of this chapter several studies were mentioned that investigated the influences of different factors on the implementation of practices. Size is an important influence that can influence the use of practices in different production systems. White et al. (1999) concluded that larger sized companies have a higher implementation of practices then small companies.

H_3: The size of a company has a positive influence on the relationship between production system and the use of practices.

Most publications about the Lean concept start with the severe competition due to continuously increasing globalization (Shah and Ward, 2003, Nakamura et al., 1998). Competition is present if similar of substitutable products are offered by multiple companies. However, if a company is able to distinct itself from others by developing new product or processes pressure to use of lean concepts is lower (Hayes and Pisano, 1994). The influence of innovativeness on the relationship between production system and the use of practices will be taken into account for this study and hypothesized as:

H_4: Innovativeness will have a negative influence on the relationship between production system and the use of practices.

Innovativeness can be judged on 2 dimensions, both product and process innovation (Tsao and Wang, 2005). This leads to four different forms of innovation for companies: none, product innovation, process innovation and both product and process innovation.
H_2, H_3 and H_4 are interaction effects; they investigate the influence on a relationship. Not only will we analyze the interactive effects, but we will analyze the direct effect of these influences as well. This leads to the research model in Figure 5. The next section will discuss the methodology for this study.

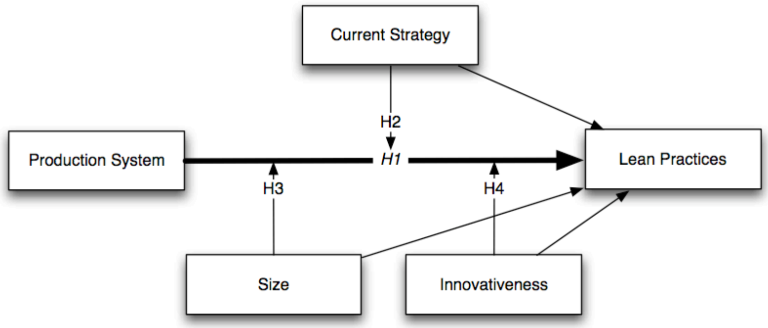


Figure 5: Research Model

3. Methodology

To test the hypotheses, stated in chapter two, data is required from practitioners. The population is the professional society. To ensure a high response rate a brief, internet-based questionnaire was chosen as the medium. A link was posted on the website that contained al information about and registration of a seminar on Lean Manufacturing. This seminar was open to all companies in the region. Participants that were already registered when the survey was posted received an email with the request to fill out the brief questionnaire. The email contained a direct link to the online questionnaire.

Questionnaire

The survey contained 9 questions (see appendix 1, a translation is provided, the original survey was in Dutch). The strategy question was split in two. The first question asked what the current strategy was. The second question asked what strategy used to set the company apart from its competitors. This enabled the tracking the use of practices along the development of these concepts, from Lean to Agile and QRM. To ensure correct answers for the production system, definitions for the ETO, MTO, ATO and MTS systems were provided.

The questions on practices (Q5, appendix 1) were to be answered in four options; a practice is either in use, to be used in the future, the practice was considered inappropriate for the company, or the respondent was unknown with the practice. For each practice a definition was given and for most practices exemplary techniques were provided. An open question was posed to cover techniques that were installed on the premise of the lean concept but that they were unable to classify.

4. Data

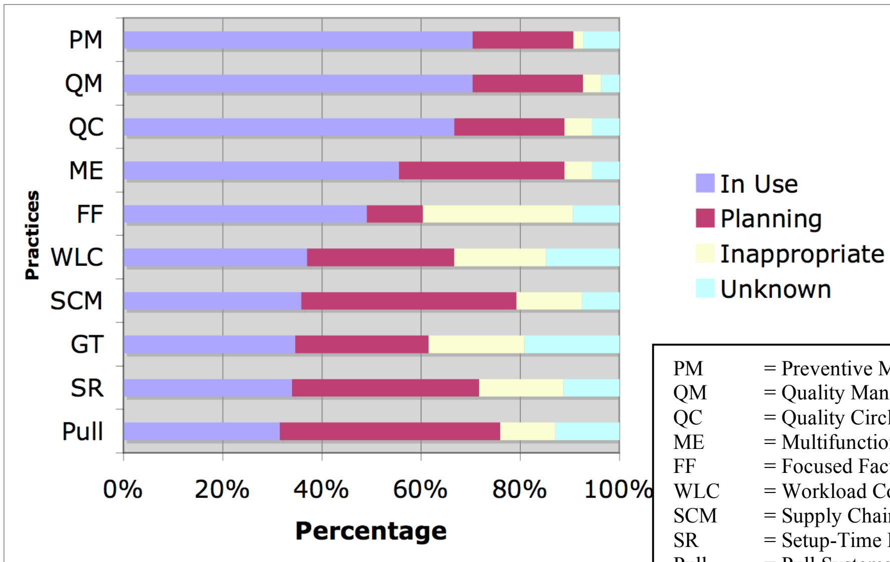
The online questionnaire was submitted 55 times. All response was received after the email was send. This could suggest a positive bias in the sample since the recipients of the email had all registered for the seminar and showed an interest in The Lean Manufacturing concept. Respondents represented a broad range of industries from consumer electronics to energy producers, and even service companies. Of these companies 31% was employed less then one hundred people, 38% between one and five hundred, and 31% more then five hundred. The ratio of production systems represented was 20% ETO, 31% MTO, 29% ATO and 16% MTS. In their study White and Prybutok (2001) found a ratio of 49% repetitive production systems (MTS and ATO) against 51% with a non-repetitive production systems (MTO and ETO). The ratio between MTS-ATO and MTO-ETO production systems is similar (47% to 53%) to the study of White and Prybutok (2001).

Rejection and recoding

Two respondents left multiple questions open. The first left all questions blank and was therefore rejected as a respondent. The second left several categories open and commented in question 18 that some categories of lean manufacturing concepts did not apply for the company he represented. Since column three was establish as inappropriate for the company the answers that were left open were recoded with a three. This left 54 respondents. The remaining correspondents were checked on similarity and there was no pair with a less then 20% difference and therefore all were accepted.

Results

On average companies use 4,8 practices. Quality Circles, Quality Management, Preventive Maintenance and Multifunctional Employees are in use at more than 60% of the companies in the sample. These categories are most in use. Most likely they will remain the most in use, with the planned implementation added to the percentage in use they score the highest percentage. Supply Chain Management, Setup-Time Reduction and Pull System are the practices that can be expected to be adopted the most in the future. The more technical categories such as Group technology and Workload control are less used and receive less attention in the future (Figure 6). The range of implementation per practice is 31% for the pull systems to 70% for preventive maintenance whereas the range of White and Prybutok (2001) extends from 59% to 85%. This supports their suggestion that their sample might be positively biased.



PM	= Preventive Maintenance
QM	= Quality Management
QC	= Quality Circles
ME	= Multifunctional Employees
FF	= Focused Factories
WLC	= Workload Control
SCM	= Supply Chain Management
SR	= Setup-Time Reduction
Pull	= Pull Systems

Figure 6: Use of Practices

The respondents were well distributed over the different classifications. All production systems, strategies, size- and innovativeness degrees were well represented, only speed was observed in less then 10% of the sample.

The fact that the range of frequencies that was found in this investigation was low compared to the study of White and Prybutok (1999) suggests that the positive bias that was expected earlier in this chapter is not very profound.

5. Analysis

In their analyses White and colleagues (White et al., 1999 & White and Prybutok, 2001) used odds ratios to determine the possibility for implementation of each practice for the specific group: big, small, repetitive or non-repetitive. This procedure however will not test the hypotheses that were formulated for this examination. This analysis entails multiple variables. There are three techniques analysis the relationship between multiple sets of variables: regression models, multi discriminant analysis and logistical regression, and analysis of variance (ANOVA). Regression models require that both dependent and independent variables are metric. Multi discriminant analysis and logistical regression requires the independent variables to be metric (Hair, Black, Babin, Anderson and Tatham, 2006). Since production systems, strategy, and innovativeness are non-metric independent variables. Therefore ANOVA was used for this analysis. An ANOVA test verifies if the mean of subgroups can be considered equal to the mean of the entire group. An ANOVA design requires that N = 25* the number of cells. In case H_1, were there are four cells, N > 100 would be required (Hair et al., 2006). Our sample consisted of 54 cases this was on not enough to ensure the outcomes, but ANOVA still provided an indication if there was a difference between the subgroups, and further analysis was useful. For an indication the critical t-value (F) had to approach or be larger then 1,96, with a significance close too or below ,05 (Hair et al., 2006).

For H_2, H_3 and H_3, which were posed as interaction effects, the number of cells, and therefore cases, had to be multiplied by three or four. Therefore the reliability could no longer be assumed. Therefore we cannot test H_2, H_3 and H_3. But we will analyze the direct effects with an ANOVA designs.

Additional analysis consisted of assessing group difference with independent T-Tests. A T-test is a specific ANOVA that analyzes the mean difference between two groups, and not between group and subgroup. A significant difference is established if Sig. 2-tailed < ,05 and the low and upper 95% confidence intervals are ≠ 0. The first step in analyzing T-Test results is to verify if equal variances are assumed (Sig. > ,05) or not assumed (Sig. < ,05)

This alteration with the addition of the former strategy led to a change in the research model.

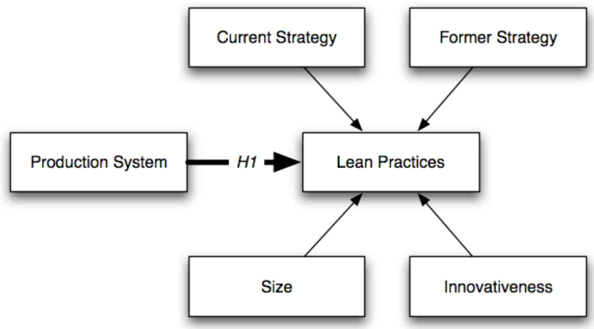


Figure 7: New Research Model

ANOVA

Table one shows the outcome of the ANOVA analyses. For production systems F approaches the critical t-value (F = 1,576), but the significance level of ,207 prevents us from rejecting H_1. However these values do suggest that there is a difference between the groups. In the next section we will continue the analysis for the production systems.

Groups	F	Sig.
Production System	1,576	,207
Strategy	,311	,869
Former Strategy	4,485	,004
Innovativeness	2,291	,090
Size	1,553	,222

Table 1: Summary of ANOVA results

There is no significant difference between the strategies (Table 1). F is far too small and Sig. far too large to suggest a difference between (F = ,311, Sig. = ,869). The practices are evaluated evenly applicable for each of the strategies. As extension the relationship of the former strategy and the use of practices was also translated into an ANOVA design to test if there was an indication of difference. These results were significant (F = 4,485; Sig. = ,004). There is a group in the sample that have had a specific strategy that is different from the rest. See what strategy was different T-Tests will be conducted.

For the influence of size on the use of practices the F value approaches the critical t value (1.553), but the significance level is to low (,222) (Table 1). Again do these values suggest that there could be a size that is different from group. Therefore the size issue will be further analyzed.

The ANOVA results indicate a difference between companies that innovate their product and process, only their process, only their products or neither. F = 2,291 exceeds the critical value of t. However with Sig. = ,09 it is not significant (Table 1), and the difference in innovativeness will be further analyzed.

The results of further analysis of production system, size, innovativeness and former strategy will be elaborated on in the subsequent parts. The T-Test will show which group seems to be different from the entire group and if this group uses more or less practices.

Production System

The mean use of practices per production system is very different (Table 2). T-Tests were performed between the different production systems (Table 3, Appendix 3a). The results of the analyses were ranked according to Sig. 2-tailed in Table 3. The group that is highest in the table is considered the group most different from the rest. A T-Test between this group and the remainder of the sample was conducted to analyze if this group could be considered different from the rest of the sample.

	Classification	Mean
Production System	ETO	5,64
	MTO	3,94
	ATO	4,80
	MTS	5,78
Size	<100	4,13
	100-500	4,85
	>500	5,63
Degree of Innovativeness	No Innovation	4,39
	Product Innovation	3,80
	Process Innovation	4,29
	Both	5,95
Current Strategy	Flexibility	5,33
	Quality	4,40
	Cost	4,47
	Reliability	5,00
	Speed	5,00
Former Strategy	Flexibility	2,71
	Quality	4,13
	Cost	6,35
	Reliability	4,75
	Speed	3,67
Total		4,87

Table 2: Mean Number of Practices in Use per Classification

Groups	Sig. (2-tailed)	Mean difference	95% Confidence Interval	
MTO – ETO	,037	1,70	,108	3,282
MTO - MTS	,068	-1,84	,172	3,219
ETO - ATO	,390	,89	-3,821	,147
MTO - ATO	,379	-,81	-4,060	,387
MTS - ATO	,405	-1,03	-1,202	2,975
ETO - MTS	,888	-,14	-1,013	2,786
MTO - Rest	,070	1,34	-,111	2,784

Table 3: Summary of Results of T-Tests performed on Production Systems

This analysis shows that MTO is a significantly different from ETO and nearly significantly different from the MTS production system (Sig. = ,068). The standard error mean is large (appendix 3a), approximately half of the mean differences. This could explain why the ANOVA did not show a significant difference among the groups. The large standard error indicates that the sample size is small and this error will probably decrease as the sample grows. The fact that this standard error is so large most likely prevented the ANOVA results from declaring different groups as the independent groups still had a large overlap of variance. Increasing the sample for every production system can decrease the standard error and the results could become significant. The ATO Production system (between MTO and MTS production systems) is not different from either of the two. The result of this analysis suggests that the degree of customization has a negative relation with the use of practices. However, the ETO production system breaks this relation by having a similar mean as the MTO production system.

The influence of size

The analyses for the size, innovativeness and former strategy were approached in the same way as production systems. For size the group <100 is the most different from the others although this difference is not significant (Sig. 2- tailed = ,092, Table 4). Therefore the data strongly suggests that smaller companies (<100) use less practices than larger ones. This finding is in line with the findings of White et al. (1999).

Groups	Sig. (2-tailed)	Mean difference	95% Confidence Interval	
<100	,062	-1,50	-3,079	,079
<100 – 100-500	,340	-,72	-2,249	,799
>500	,389	-,78	-2,580	1,030
<100 - >100	,092	1,07	-,181	2,320

Table 4: Summary of Results T-Tests for Size

The influence of Innovativeness

The T-Test results (Table 5, Appendix 3b) show that companies that both innovate their product and process are different from companies that only innovate their product, and close to significantly different from companies that do no innovation when the use of practices is considered. The sig. 2-tailed for the T-Test performed between process innovation and both is also below ,20. Therefore we performed a T-Test for group of companies that innovate both their products and process and the rest of the sample (Bottom row of Table 5).

Groups	Sig. (2-tailed)	Mean difference	95% Confidence Interval	
Product - Both	,044	,070	,154	,516
No - Both	,070	,916	-2,15	-1,56
Process - Both	,154	,59	-,49	,10
No - Product	,516	-,063	-3,252	,135
Product - Process	,643	,668	-1,251	2,429
No - Process	,916	1,701	-1,891	2,097
Other - Both	,013	1,75	,391	3,104

Table 5: Summary of Results T-Tests for Innovativeness

Companies that innovate both their products and process are significantly different from the rest of the sample (Sig. 2-tailed = ,013). The most innovative companies, companies that innovate both product and process, are using more practices than other companies.

The influence of former strategy

With the ANOVA analysis we found that the former strategy has a significant different group with regard to number of practices in use. Table 6 shows that the difference between cost and all other strategies al has a Sig. 2-tailed < .08. Therefore we set up an ANOVA design that tested if cost was the group that is significantly different from the group (Table 7)[5].

[5] We chose to perform an ANOVA here since the original test results already showed that a group was significantly different from the entire group.

Groups	Sig. (2-tailed)	Mean difference	95% Confidence Interval	
Flexibility - Cost	,000	-3,64	-5,426	-1,845
Quality - Cost	,009	-2,22	-3,841	-,592
Flexibility - Dependability	,041	-2,04	-3,971	-,101
Cost - Speed	,064	2,68	-,171	5,538
Cost - Dependability	,074	1,60	-,169	3,369
Flexibility - Quality	,199	-1,42	-3,650	,812
Dependability - Speed	,488	1,08	-2,309	4,476
Flexibility - Speed	,510	-,95	-4,140	2,235
Quality - Dependability	,564	-,62	-2,804	1,571
Quality - Speed	,786	,47	-3,118	4,052

Table 6: Summary of Results T-Test for Former Strategy

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	72,364	1	72,364	14,505	,000
Within Groups	254,429	51	4,989		
Total	326,792	52			

Table 7: ANOVA Cost versus Other Former Strategies

The data that was gathered from the survey was insufficient to investigate interaction effects. This led to a change in the research model. Instead of examining the influences that were discussed in the literature review as interaction effects they were examined as direct effects on the use of practices only.

The evidence suggests that there is a negative relation between the use of practices and customization. Although significance prevented us from reject H_1. The mean of practices implemented MTO production systems turned out to be close to significantly lower than the rest of the sample. Remarkable was the high use of practices by ETO production systems. These companies are dealing with the maximum degree of customization and used as many practices as MTS production systems.

There was no evidence that suggested that there was a difference in use of practices between companies with different current strategies. However, the former strategy seems to be an important influence. Companies that used to compete on cost have a higher use of practices than others. This is in line with the development of Agile Manufacturing and QRM.

The companies smaller than 100 employees use, nearly significant, less practices than the remainder of the sample. This is in line with previous findings by White et al. (1999). The findings here are consistent with and although the distinction was different. White

(1999) observed this effect between companies smaller than 250 employees compared to companies larger than 1000 employees.

The effect that was expected for innovativeness seems to be opposite from the findings. The most innovative companies, does who innovate both product and process, use more practices than other companies.

The most clear difference was the difference use of companies that have cost as their former strategy this group's mean is significantly higher than the mean of the entire group.

6. Difference in implementation

In chapter five some interesting differences were found. However, an important question remains. What is the difference between the practices used? The analysis on use of practices per production system strongly suggests that MTO production system uses less than the rest of the sample. The growth in difference from MTO, ATO to MTS systems can be explained the decreased applicability the lean concept as variety increases (Hines et al. 2004; White and Prybutok, 2001), but why does ETO break this relationship?

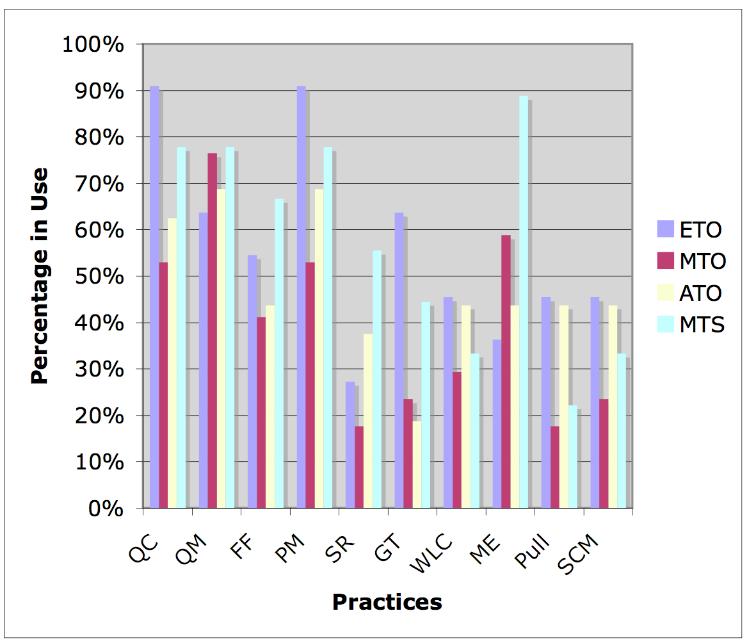


Figure 8: The Use of Practices per Production System

Figure 8 shows that use of practices is different for the production systems. ETO production systems gain their use from Quality Circles, Preventive Maintenance and the use of Group Technology. Quality Circles can be explained by the nature of work in an ETO system. Every product is newly designed and problems have to be overcome. This stimulates cooperation between workers. The high use of Group Technology in ETO production systems can be explained by the repetition in design cycles. When designing is repeated often it will be rewarding to reuse parts and processes. This can ensure quality and design cost. MTO production systems on the other hand have a low score on the use of technical practices. Setup-Time Reduction and Pull Systems are less often implemented in an MTO production system then in the other production systems. This low use of Setup-Time Reduction is remarkable. These production systems produce different products and setups will determine a large part of their efficiency. Another remarkable feature in Figure 8 is the high use of Multifunctional Employees in MTS production systems. This can be explained by the high degree of repetition in this environment. To satisfy employees apparently the companies decided to use job rotation to enrich their motivation (Job characteristics model by Hackman and Oldham, adapted from: Kreitner, Kinicki and Buelens, 1999).

Strategy

The results of the strategies former and current were expected. The applicability of the Lean concept was assumed to be in the cost strategies. That is at the lower end of the customization continuum (Hines et al., 2004). The change between former strategy and current strategy implies that the companies that used to have a cost strategy have differentiated among the other strategies. Table 8 shows the pattern of differentiation. From the 20 companies that used to have cost as strategy, only four remained with the strategy. 50% is currently trying to increase its flexibility. The other large flow is from flexibility to cost strategy. This suggests an equilibrium between cost and flexibility strategy as it is defined by Chong (1998), where the choice between cost and flexibility depends on the nature of the competitive environment in which a company operates.

Former \ Current	Flexibility	Quality	Cost	Dependability	Speed	Total
Flexibility		1	6			7
Quality	3	4	2	4	2	15
Cost	10	1	4	4	1	20
Dependability	2	3	3			8
Speed		1	1	1		3
Total	15	10	16	9	3	53

Table 8: Change in Strategy

Size

The fact that the small companies have fewer practices in use is consistent with the findings of White et al. (1999). The difference in practices is primarily based on the technical practices, Setup-time Reduction, Group Technology, Pull Systems and Workload Control (Figure 9). White et al (1999) explained that larger companies have ability to gather expertise, is applicable to these results. An important difference with findings of White et al. (1999) is that Multifunctional Employees is less in use in small companies than in larger ones. This contradicts the usual belief that in large companies have more specialized employees. This is an interesting subject for future research.

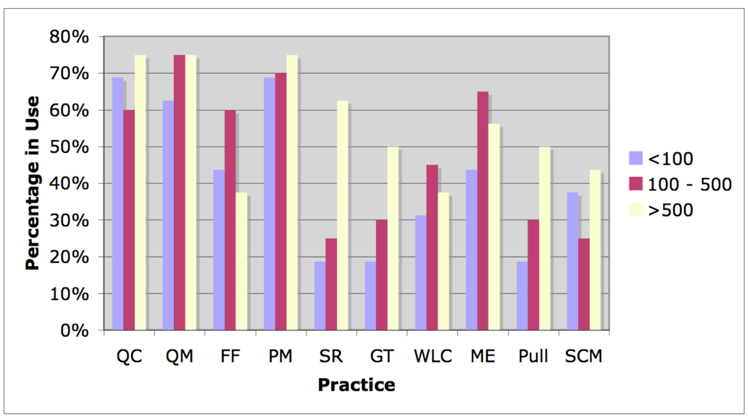


Figure 9: The Use of Practices per Size

Innovativeness

The effect of innovativeness of a company on the use of practices seems to be positively related. Companies that innovate both their product and process have a higher mean use of practices then the rest of the sample. This can be due to the culture in the company. If people are consistently exposed to change they will get accustomed to it and look for opportunities whereas people that are less frequently confronted with change are resistant (Kreitner et al., 1999). Figure 10 shows that the primary source of advantage for innovative companies is two technical practices; Setup-time Reduction and Pull Systems. The companies that are innovating just products or processes seem to be far behind in this area. As noted before change is needed to breakdown resistance against it. Apparently the companies that are accustomed to change have the ability to implement practices that are complicated.

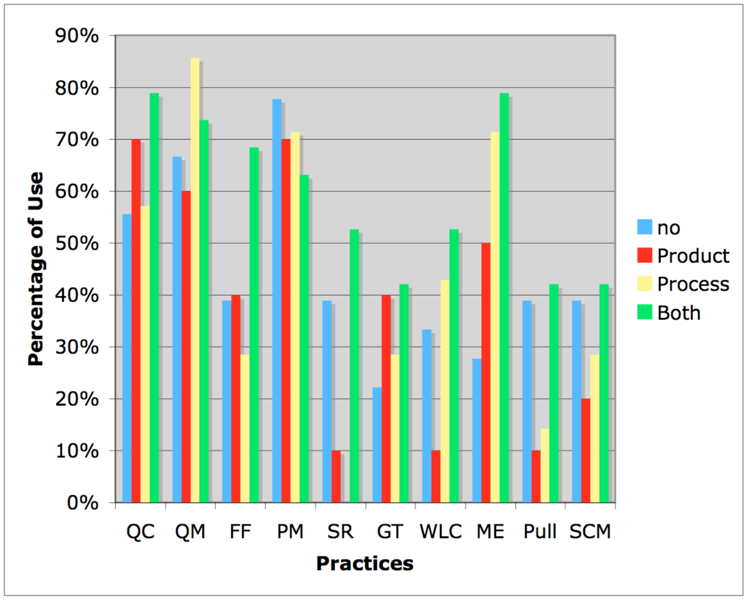


Figure 10: The Use of Practices per Degree of Innovativeness

The results of this study are different then the hypotheses that were posed in chapter 2. H_1 and H_3 were hypotheses were stated to test how recent scientific developments are being adopted in practice. Because the sample size prevented use from testing H_3, the interaction effect of strategy on the relationship between production system and the use of practices, instead the direct effect of strategy was analyzed and it seems that the developments of Agile manufacturing and QRM, have found its footholds in practice by differentiating from the cost strategy to other strategies. This is opposite from the conclusion that could be drawn from the analysis on production systems, were lower increased customization had a negative influence on the use of practices. This could be explained be the delay that between strategy, a vision of where to go, and the actual current performance. It can be expected that the use of practices will further differentiate among different production systems in the future.

Discussion and conclusions

The aim of this study was to discover how the theoretical developments of production concepts have been adopted in practice. The main focus was the relationship between customization and the use of practices that traditionally contained techniques to support the Lean concept. The customization continuum was divided into parts that related with the moment a product was made specific for an individual customer. The distinctions were (decreasing in customization): ETO, MTO, ATO and MTS production systems. The findings from the analysis suggest that there is still a negative relation between the degree of customization and the use of practices from the Lean concept. However, the companies with an ETO production system, that deliver pure customization, break this relationship, and use as many practices as companies with an MTS production system. Although the evidence suggests this relation, the sample size was too small to verify its significance. Future research should entail an extension of this survey to gather more data.

Beside the relation with the customization the influence of the company's size, strategies, former and current, and their innovativeness was examined. The small sample prevented an analysis of interaction effect, but an important factor in the use of practices is the former strategy, companies that have focused on cost use more practices then companies that have focused on different goals. The fact that the current strategy has no influence is important. This validates the development of Agile Manufacturing and QRM, because practitioners are applying the practices within in a broader range of strategies. The fact that no distinction can be made between the current strategy and the mean number of practices implemented indicates that the adoption of will further grow every production system and therefore in every degree of customization.

A prerequisite for the adoption seems to be a culture that is open for change. The influence of innovativeness showed that companies that innovate both their products and their processes use the most practices and even adopt the most technical practices. However the exact reason for this should be further investigate,

The available capital is a significant issue as well. Larger companies have more practices in use than small companies. Companies need to gain expertise to implement the lean concept, and this can either be bought or gained from assigning people specifically to guide implementation. Large companies have more capital available to gather this expertise.

Al though possible explanations have been given to the question that arose from this research should be done on the questions that remain: First, why do companies that are at the opposite end of the customization continuum adopt more practices than companies in the middle of the spectrum? Second, why do companies that have an innovative nature adopt Lean concepts more then companies that more subject to the increased competition? And third, will the adoption of production concepts continue in the future?

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Appendix 1: Survey

Research in the use of Practices

Declaration of anonymity and proper use of the information gathered.

Q1. **To judge the innovativeness of a company often a distinction is made between product- and process development. Choose from the alternatives given below the most suitable to characterize your company.**

a. We are producing the same product with the same technology for years.
b. We continuously introduce new products in the market place
c. We continuously apply new technology in our production process
d. We continuously introduce new products in the market place and apply new technologies in our production process

Introduction to question 2:
The degree of customization of products can be characterized using a typology for the production system. The following typology is often used:

Engineer-to-Order:	*For each order a specific design is made based on the customer's requirements.*
Make-to-Order:	*Product designs are available but production is started after an order is received.*
Assembly-to-Order:	*The basic building blocks for the product are in stock, the final assembly is done after an order is received.*
Make-to-Stock:	*Products are shipped to the customer from stock*

Q2. **Chose from the descriptions above the production system that your company applies for the majority of products.**

a. Engineer-to-Order
b. Make-to-Order
c. Assembly-to-Order
d. Make-to-Stock

Introduction to questions 3 and 4:
Distinction between companies can be made based on production strategy. Complete the following statements for your company.

Q3. **We want to improve ourselves primarily on……**

a. Flexibility
b. Quality
c. Cost
d. Reliability
e. Speed

Q4. **In the past we have improved ourselves primarily on……**

a. Flexibility
b. Quality
c. Cost
d. Reliability
e. Speed

Q5. **Lean management practices can be separated in ten categories. Determine for each category if your company uses practices, if your company is planning the implementation, if the practice is considered inappropriate for your company or if you are unfamiliar with that category.**

	In Use	Planning	Inappropriate	Unknown
Quality Circles Practices that encourage employees to participate in problem solving and decision-making.	☐	☐	☐	☐
Quality Management Practices that make Quality a priority for all members of the organization and suppliers. *Examples: TQM, ISO, SPC, 6 Sigma*	☐	☐	☐	☐
Focused Factory Dedication of machine and/or space in the factory for the production of a specific product or productgroep. *Examples: Production line, Cellular manufacturing*	☐	☐	☐	☐
Preventive Maintenance Routinely perform maintenance Small maintenance procedures are performed by operators.	☐	☐	☐	☐
Setup-time Reduction Practices to shorten the setup-time for machines and minimize the changing of tools, to accommodate production in smaller batches. *Example: SMED*	☐	☐	☐	☐

Group Technology Practices that use grouping or clustering to generate efficiencies in product design and production.	☐	☐	☐	☐
Uniform Workload Practices to generate a uniform workload based on order acceptance. *Examples: MPS, Leveled Scheduling*	☐	☐	☐	☐
Multifunctional Employees Practices to enable placement of employees at different machine and/or different functions.	☐	☐	☐	☐
Pull System Practices of material handling based on demand or available capacity. *Examples: Kanban, Polca, ConWIP, Workload Control*	☐	☐	☐	☐
JIT Supply/Supply Chain Management Practices in cooperation with suppliers to enhance quality, flexibility, and service level by the supplier and decrease the number of suppliers.	☐	☐	☐	☐

Q6. **If there are practices that your company has applied that can not be placed in a category, then you can write down the name below:**

____

Q7. **What is your function within the company?**

____

Q8. **Name of your company**

____

Q9. **What is the size of your company**

a. less then 100 employees
b. between 100 and 500 employees
c. more then 500 employees

Q10. **If you are interested in the results of this research then you can submit your email address below.**

Thank you for filling out this survey.

Appendix 2: ANOVA Output

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	38,750	3	9,583	1.576	,207
Within Groups	298,042	49	6,082		
Total	326,792	52			

Table 9: ANOVA Mean number of Practices in Use per Production System

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8,180	4	2,045	,311	,869
Within Groups	321,969	49	6,571		
Total	330,148	53			

Table 10: ANOVA Mean Number of Practice in use per Strategy

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	39,894	3	13,298	2,291	,090
Within Groups	290,254	50	5,805		
Total	330,148	53			

Table 11: ANOVA Mean Number of Practices per Degree of Innovativeness

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	18,008	2	9,004	1,553	,222
Within Groups	284,050	49	5,797		
Total	302,058	51			

Table 12: ANOVA Mean Number of Practices Per Size

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	88,914	4	22,228	4,485	,004
Within Groups	237,879	48	4,956		
Total	326,792	52			

Table 13: ANOVA Mean Number of Practices per former strategy

Appendix 3a: T-Tests for the Production Systems

Group Statistics

Production System	N	Mean	Std. Deviation	Std. Error Mean
ETO	11	5,64	1,748	,527
MTO	17	3,94	2,135	,518
ATO	16	4,75	3,022	,756
MTS	9	5,78	2,682	,894

Groups compared		Levene's Test for Equality of Variances: F	Sig.	t-test for Equality of Means: t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference: Lower	Upper
MTO - ETO	Equal variances assumed	,290	,595	2,196	26	,037	1,70	,772	,108	3,282
	Equal variances not assumed			2,294	24,411	,031	1,70	,739	,172	3,219
MTO - MTS	Equal variances assumed	1,153	,294	-1,911	24	,068	-1,84	,961	-3,821	,147
	Equal variances not assumed			-1,778	13,508	,098	-1,84	1,033	-4,060	,387
ETO - ATO	Equal variances assumed	3,866	,060	,874	25	,390	,89	1,014	-1,202	2,975
	Equal variances not assumed			,962	24,461	,345	,89	,921	-1,013	2,786
MTO - ATO	Equal variances assumed	2,650	,114	-,892	31	,379	-,81	,906	-2,658	1,040
	Equal variances not assumed			-,883	26,849	,385	-,81	,916	-2,689	1,071
MTS - ATO	Equal variances assumed	,173	,682	-,848	23	,405	-1,03	1,212	-3,535	1,479
	Equal variances not assumed			-,878	18,479	,391	-1,03	1,171	-3,482	1,427
ETO - MTS	Equal variances assumed	2,804	,111	-,142	18	,888	-,14	,994	-2,231	1,948
	Equal variances not assumed			-,136	13,245	,894	-,14	1,038	-2,379	2,096

Production System	N	Mean	Std. Deviation	Std. Error Mean
Rest	36	5,28	2,581	,430
MTO	17	3,94	2,135	,518

Groups compared		Levene's Test for Equality of Variances: F	Sig.	t-test for Equality of Means: t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference: Lower	Upper
MTO - Rest	Equal variances assumed	1,547	,219	1,854	51	,070	1,34	,721	-,111	2,784
	Equal variances not assumed			1,985	37,535	,054	1,34	,673	-,027	2,700

Appendix 3b: T-Tests for Size

Group Statistics

Size	N	Mean	Std. Deviation	Std. Error Mean
<100	16	4,13	1,746	,437
100-500	20	4,85	2,720	,608
>500	16	5,63	2,553	,638

Groups compared		Levene's Test for Equality of Variances F	Levene's Test for Equality of Variances Sig.	t-test for Equality of Means t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper
<100 - >500	Equal variances assumed	3,211	,083	-1,940	30	,062	-1,50	,773	-3,079	,079
	Equal variances not assumed			-1,940	26,518	,063	-1,50	,773	-3,088	,088
<100 – 100-500	Equal variances assumed	6,194	,018	-,923	34	,362	-,72	,785	-2,321	,871
	Equal variances not assumed			-,968	32,647	,340	-,72	,749	-2,249	,799
100-500 - >500	Equal variances assumed	,275	,603	-,873	34	,389	-,78	,888	-2,580	1,030
	Equal variances not assumed			-,879	33,078	,386	-,78	,882	-2,568	1,018

Group Statistics

Degree of Innovativeness	N	Mean	Std. Deviation	Std. Error Mean
<100	16	4,13	1,746	,437
>100	36	5,19	2,638	,440

Groups compared		Levene's Test for Equality of Variances F	Levene's Test for Equality of Variances Sig.	t-test for Equality of Means t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper
<100 - >100	Equal variances assumed	5,634	,022	1,479	50	,145	1,07	,723	-,382	2,521
	Equal variances not assumed			1,726	42,239	,092	1,07	,620	-,181	2,320

Appendix 3c: T-Tests for Innovativeness

Group Statistics

Degree of Innovativeness	N	Mean	Std. Deviation	Std. Error Mean
No Innovation	18	4,39	2,279	,537
Product Innovation	10	3,80	2,251	,712
Process Innovation	7	4,29	1,799	,680
Both	19	5,95	2,758	,633

Groups compared		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Product - Both	Equal variances assumed	,404	,530	-2,114	27	,044	-2,15	1,016	-4,232	-,063
	Equal variances not assumed			-2,255	21,982	,034	-2,15	,952	-4,123	-,172
No - Both	Equal variances assumed	,390	,536	-1,868	35	,070	-1,56	,834	-3,252	,135
	Equal variances not assumed			-1,878	34,383	,069	-1,56	,830	-3,245	,128
Process - Both	Equal variances assumed	1,173	,290	-1,472	24	,154	-1,66	1,129	-3,991	,668
	Equal variances not assumed			-1,789	16,710	,092	-1,66	,929	-3,624	,301
No - Product	Equal variances assumed	,026	,874	,658	26	,516	,59	,895	-1,251	2,429
	Equal variances not assumed			,660	18,920	,517	,59	,892	-1,278	2,456
Product - Process	Equal variances assumed	,385	,544	-,473	15	,643	-,49	1,026	-2,673	1,701
	Equal variances not assumed			-,493	14,636	,629	-,49	,985	-2,589	1,617
No - Process	Equal variances assumed	,658	,426	,107	23	,916	,10	,964	-1,891	2,097
	Equal variances not assumed			,119	13,908	,907	,10	,867	-1,757	1,963

Degree of Innovativeness	N	Mean	Std. Deviation	Std. Error Mean
Other	35	4,20	2,139	,362
Both	19	5,95	2,758	,633

Groups compared		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Other - Both	Equal variances assumed	1,102	,299	2,585	52	,013	1,75	,676	,391	3,104
	Equal variances not assumed			2,398	29,982	,023	1,75	,729	,259	3,236

Appendix 3d: T-Tests for the former strategy

Group Statistics

Former Strategy	N	Mean	Std. Deviation	Std. Error Mean
Flexibility	7	2,71	1,496	,565
Quality	15	4,13	2,615	,675
Cost	20	6,35	2,110	,472
Reliability	8	4,75	1,909	,675
Speed	3	3,67	3,055	1,764

Groups compared		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Flexibility - Cost	Equal variances assumed	1,007	,325	-4,182	25	,000	-3,64	,869	-5,426	-1,845
	Equal variances not assumed			-4,937	14,968	,000	-3,64	,736	-5,206	-2,066
Quality - Cost	Equal variances assumed	,219	,643	-2,777	33	,009	-2,22	,798	-3,841	-,592
	Equal variances not assumed			-2,691	26,372	,012	-2,22	,824	-3,909	-,525
Flexibility - Reliability	Equal variances assumed	,726	,410	-2,273	13	,041	-2,04	,896	-3,971	-,101
	Equal variances not assumed			-2,312	12,875	,038	-2,04	,880	-3,940	-,132
Cost - Speed	Equal variances assumed	,504	,486	1,955	21	,064	2,68	1,373	-,171	5,538
	Equal variances not assumed			1,470	2,295	,264	2,68	1,826	-4,280	9,646
Cost - Reliability	Equal variances assumed	,060	,808	1,859	26	,074	1,60	,861	-,169	3,369
	Equal variances not assumed			1,943	14,258	,072	1,60	,823	-,163	3,363
Flexibility - Quality	Equal variances assumed	1,133	,300	-1,327	20	,199	-1,42	1,069	-3,650	,812
	Equal variances not assumed			-1,611	18,868	,124	-1,42	,881	-3,263	,425
Reliability - Speed	Equal variances assumed	,870	,375	,722	9	,488	1,08	1,500	-2,309	4,476
	Equal variances not assumed			,574	2,612	,612	1,08	1,889	-5,464	7,631
Flexibility - Speed	Equal variances assumed	2,425	,158	-,689	8	,510	-,95	1,382	-4,140	2,235
	Equal variances not assumed			-,514	2,424	,650	-,95	1,852	-7,725	5,820
Quality - Reliability	Equal variances assumed	,284	,600	-,586	21	,564	-,62	1,052	-2,804	1,571
	Equal variances not assumed			-,646	18,674	,526	-,62	,955	-2,617	1,384
Quality - Speed	Equal variances assumed	,086	,773	,276	16	,786	,47	1,691	-3,118	4,052
	Equal variances not assumed			,247	2,621	,823	,47	1,889	-6,067	7,000