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Management capabilities and application of complex automated systems

Kadri Kristjuhan[a], Ergo Metsla[b] and Hannes Ling[b]

[a] Growth Companies Inc., WTC Tallinn, Ahtri 8, 10151 Tallinn, Estonia; kadri.kristjuhan@growthcompanies.eu
[b] Tallinn School of Economics and Business Administration, Tallinn University of Technology, Akadeemia tee 3, 12618 Tallinn, Estonia; ergo.metsla@tseba.ttu.ee, hannesling@smail.ee

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Abstract. Management innovation scholars over the last decade and quality management authorities over several past decades have indicated that companies need effective management practices in order to utilize complex automated systems. However, empirical evidence for a relationship between companies' management and technological capabilities has been lacking. This study plugs an important gap in empirical evidence of the relationship between companies' management capabilities and application of complex automated systems. A pilot study was conducted in Estonian companies, which apply robot welding. Evidence of a strong correlation (correlation coefficient of 0.74) between companies' management capabilities and effectiveness in utilizing this complex technology was shown. The study also revealed a novel survey instrument for studying companies' management and technological capabilities.

Key words: quality of management, management technological and organizational capabilities, complex automated systems.

1. INTRODUCTION

Management innovation theory suggests that companies, which do not possess effective management practices, are not capable of utilizing economically beneficially complex technological systems [1]. Also, quality authorities, such as Mizuno [2] and Kondo [3], have argued that applying automated systems presupposes excellently planned and coordinated processes, superb information flow, and standardized and disciplined operations. Such processes and operations presume high quality of management at the middle and frontline levels of an organization which are supported by clear direction from the top management.

However, empirical evidence of a relationship between companies' management capabilities and ability to utilize complex automated systems has been lacking.

Recent research in Estonia has indicated that management capabilities in companies are relatively low both at the company level as well as at the operational production management level [4,5]. Yet, in recent years a number of Estonian manufacturers have invested in complex technology. Their overall assessment of their technological potency is satisfactory [5]. From the 2011 Estonian machine building sectorial study follows that in the majority of Estonian machine building companies the level of management capabilities is low both at the company level and at the operational production management level [6]. Nevertheless, nearly half of the companies, participating in the study, admitted having revamped their manufacturing processes by greater automation and implementation of novel technologies, such as laser cutters, welding robots and 3D measuring equipment [6].

This paper argues that, in accordance with theoretical perspectives, there exists a strong positive correlation between the companies' management capabilities and its capability to utilize complex automated equipment, such as a welding robot. Management capabilities have been defined as and limited to the quality of management practices. Management practices have been defined as a set of Luthans and Lockwood management practices as explained in [7] and limited to the practices of an effective manager as described in [8]. The quality of management practices is measured as the level of application of management practices, in scope and depth, in a company. The scope is operationalized by the proportion of employees who are involved in the practice, and the depth by the regularity of the practice, and by documenting and publishing the results. It is inferred that conditions exist at which the company's capability to utilize the complex automated equipment is maximized.

2. THEORETICAL FRAMEWORK

2.1. Management practices

A number of studies have been carried out over the past half a century to identify what is it that managers do in their daily work. The majority of such studies have been in the form of an observation of the managers' work. Also interviews with managers and document reviews have been used.

An exception to the above described line of research was Henri Fayol, who was a top manager himself as well as a scholar. Fayol was one of the first to propose a comprehensive theory of management. He posited that there were five principal functions of management: planning, organizing, coordinating, leading and controlling [9]. Fayol defined planning as forecasting with the aim of analysing the future and drawing up a plan of action. Organizing was described as structuring the organization, processes and tasks. Coordinating stipulated that managers allegate, unify and harmonize the organisation's activities and efforts. A synonym applied for "leading" was "commanding", but the term was con-

ceptualized as a manager's responsibility to lead, direct and motivate employees towards the achievement of organizational goals and strategies [9].

For Fayol, controlling was the most important function of management since without controlling, he reasoned, carrying out other functions was impossible. Controlling ensured successful implementation of other functions. It involved exercising appropriate management to ensure that all processes and operations were working according to a plan and within budget and set timescales [9].

Later, management specialists have often reduced the five management functions to four by removing coordination. Their argument has been that coordination is an inherent ingredient of the other management functions and needs to be carried out simultaneously with these (e.g. [10]).

Drucker, a much cited author in the field of management, who primarily carried out his research by non-participant observation and conceptualization, modified the terms of management functions to setting objectives, organizing, motivating, and measuring [11]. Also, he called these terms the "basic operations" of management instead of functions.

Drucker's "setting objectives" was a somewhat narrower concept than Fayol's "planning", meaning determining objectives and goals and specific activities to reach these goals and objectives. By Drucker, decision making was an important part of setting objectives. It required analytical and synthesizing abilities. In brief, Fayol's "planning" could be seen as a broader concept, of which Drucker's "setting objectives" would be a part of [9,11].

Drucker defined "organizing" the same way as Fayol. Also, Drucker's concept of "motivating" is comparable to Fayol's "leading" with the exception that Drucker added the activities of developing people as compulsory components of leading [9,11].

Measuring by Drucker meant analysing performance, appraising it, and interpreting it. It is important to emphasize that for him a person's self-control was more important and effective than control inflicted by external factors. Aside from that, Drucker's and Fayol's approaches to controlling and measuring were identical [9,11].

Alternatively to Fayol's line of conceptualization, Mintzberg and Kotter carried out their own original studies into what managers do. Mintzberg observed activities of five top managers over a five day period and proposed 10 roles of managers based on the observations [12]. Kotter observed work of 15 top managers (for more than 600 hours in total) and additionally collected information from different documented sources in organizations [13].

The limitations of the Mintzberg and Kotter studies were that, first, the number of managers observed was very small. Second, both scholars only directly observed top managers of organizations. Yet other scholars, such as Mizuno [2] and Kondo [3], have argued that, in fact, the most important level of management in terms of delivering quality products and services to customers was the frontline management. It has been a prevailing stance among the Western (such as European and North-American) scholars that strategy development

(Fayol functions of planning and leading) is primarily the responsibility of the top management of an organization, while the middle-management should focus on strategy implementation (Fayol functions of organizing and controlling) [14]. Albeit, several studies cited in [15] have shown that managers at all levels of an organization participate in planning, coordinating, controlling, and problem solving.

Third, Mintzberg was focused on the behaviour of the studied top managers, rather than on their functions. Finally, later empirical research has failed to confirm some of Mintzberg's and Kotter's conclusions, e.g., distinct existence of Mintzberg's ten managerial roles has not been confirmed [15].

Fayol's model of management functions, on the other hand, has stood the test of time [15]. A number of scholarly works have applied these functions directly in empirical research or based research models on them. For example, the "PRINCESS" factors study by Mahoney, Jerdee, and Carroll, cited in [15], extended Fayol's five functions to eight factors: planning, representing, investigating, negotiating, coordinating, evaluating, supervising and staffing. The study investigated time allocation of managers on the listed factors.

Another indication of a theory's descriptiveness is if independent studies of the same phenomenon reach similar results. An independent study by Luthans and Lockwood in 1984, cited in [7], applied an observation method to measure behavioural frequency of managerial activities. The study identified 12 categories of managerial activities (hereafter called management practices): planning/ coordinating, staffing, training/developing, decision making/problem solving, processing paper work, exchanging routine information, monitoring/controlling performance, motivating/reinforcing, disciplining/punishing, interacting with outsiders, managing conflict and socializing/politicking [7]. The Luthans and Lockwood management practices can be easily conceptually related to Fayol functions with the exception of socializing/politicking. The latter practice encompasses nonwork-related chit-chat and gaming [7] and thus was not the object of Fayol's studies. The results of the authors' conceptualization of the relationship between Fayol functions, and Luthans and Lockwood practices have been provided in Table 1.

Luthans and Lockwood management practices have been successfully operationalized by Luthans and his colleagues in later research as well as by other scholars. Some examples include Asllani and Luthans' study of knowledge managers [16], and O'Driscoll, Humphries and Larsen's study of links between performance of managerial activities and perceived managerial effectiveness [17].

In this study a set of Luthans and Lockwood management practices and detailed descriptions of activities, as cited in [7] and limited to the practices of an effective manager [8], have been operationalized to define management practices, quality of which is measured in relation to the companies' technological performance. The management practices and activities will be detailed in Section 3 of this article.

Table 1. Comparison of Fayol functions and Luthans and Lockwood management practices (authors' conceptualization)

Fayol management functions [9]	Luthans and Lockwood management practices [7]
Planning	Planning/coordinating
Coordinating	Exchanging routine information Interacting with others Decision making / problem solving
Organizing	Staffing Processing paperwork
Leading	Training/developing Motivating/reinforcing Disciplining/punishing Managing conflict
Controlling	Monitoring / controlling performance
–	Socializing/politicking

In addition, questions have been asked from the respondents regarding the level of management at which these activities are most actively practiced in the company. This is to shed light to whether the decades old Western tradition of segregating between the activities of different levels of management in a company bears any ground [14]. Or, perhaps an Asian concept of every person being responsible for his/her own self-reflection, as well as reflection on his/her activities in the company, and planning and carrying out the actions contributed best to the company's performance [2,3].

In this study, the performance under investigation is highly specific. It is the companies' technological capability to utilize complex automated systems, such as robot welding. Thus the Western scholars' hypotheses are constructed as follows:

H1a: *In the management practices respective to Fayol's functions of planning and leading the top management of the company has more impact on the performance of utilizing the complex automated systems than does middle-management*;

H1b: *In the management practices respective to Fayol's functions of organizing and controlling, the middle-management has more impact on the performance of utilizing the complex automated systems than does the top management*.

This leaves one with a question of what to do with the frontline management. In the Western literature until the 21st century such a concept was hardly existent unless a union related subject was discussed. For the purposes of this study, the frontline management activities are equalized with those of the middle-management.

2.2. Management practices and performance

While classical economics and its related organization theories, such as the industrial organization, tend to downplay the role of managers in a company's performance, management scholars are determined that managerial activities have a significant role in a company's results [18]. Yet, due to the complexity of defining management and the large variety of factors influencing company performance, investigations into how management relates to company performance are scarce.

Moreover, how to measure companies' performance is a surprisingly unspecified area [19]. Still recently attempts have been made to organize the various measures applied in scholarly research into organizational performance and organizational effectiveness measures. Organizational effectiveness is a broader concept in this arrangement, which captures organizational performance measures, as well as a plethora of internal and external performance measures, normally associated with more efficient, effective or sustainable operations [19]. The organizational performance measures encompass traditional accounting and stock market measures, such as profitability, return on assets, return on investment, total shareholder return, and economic value added. Also product market performance measures, such as sales and market share, would be categorized as organizational performance measures [19]. While scholars, conducting large-scale research with panel data, tend to prefer the organizational performance measures due to their perceived objectivity, comparability, and availability in public databases, some research has indicated that other organizational effectiveness measures might be more robust in projecting an organization's long-term success (e.g., see example on pp. 728 and 735 in [19]).

The following studies into outcomes of the managerial activity use a number of varied organizational effectiveness measures. Horovitz and Thietart made an early attempt to find relations between classical managerial functions of organizing, planning and controlling, and firm performance by controlling for company size and industry sector [20]. "Good management principles" (the term used in [20]) was related to "good performance" in [20].

Bloom and van Reenen used a complex survey instrument to collect data on company practices and compared these to company performance in the form of accounts and the stock market data [21]. This study also found that better management practices were associated with better company performance, including higher productivity, profitability, and survival. However, the survey instrument was not theoretically founded.

Svirina measured the efficiency of Fayol's functions and company performance (e.g. planning accuracy, quality of motivation, profitability, financial stability, and market share) [22]. One of the results of the study suggested that spending time and money on performing motivational functions was more effective than an equal distribution of resources.

In this study the quality of management practices is measured as the level of application, in scope and depth, of management practices in a company. The scope is operationalized by the proportion of employees who are involved in the practice and the depth by regularity of the practice, and by documenting and publishing the results. Depth increases as the company goes from irregular practices to regular practices, and from not documenting the results to documenting and making available the results of the practices. It is inferred that such level of application of management practices exists at which the company's capability to utilize complex automated equipment is maximized. At other levels of application of management practices, the capability to utilize complex automated equipment is suboptimal and thus defective. The general structure of the study is depicted in Fig. 1.

While the available studies into outcomes of the managerial activity used a number of organizational effectiveness measures, both studies applying a single measure and those applying several different measures to assess a factor's relationship to the company's performance can be found in the literature. A researcher must choose a measure or measures of performance which best help to answer the research question rather than pick the one easiest available. Theory recommends to have a clear understanding of which measures would be appropriate to the research context as well as whether and how to combine several measures [19]. This study investigates a relationship between companies' management capabilities and technological performance. An appropriate measure is an operational, that is, an organizational effectiveness measure. The most demanding effectiveness measure for assessing the use of technology from the point of view of organizational attainment is the right first time (also referred to as "first-time-right"). The latter measures the frequency of producing, minus defects and rework [23]. It is evident from this basic formula that the measure has cost implications for the company. Thus the measure chosen to assess the companies' technological performance in this study is a single right first time measure.

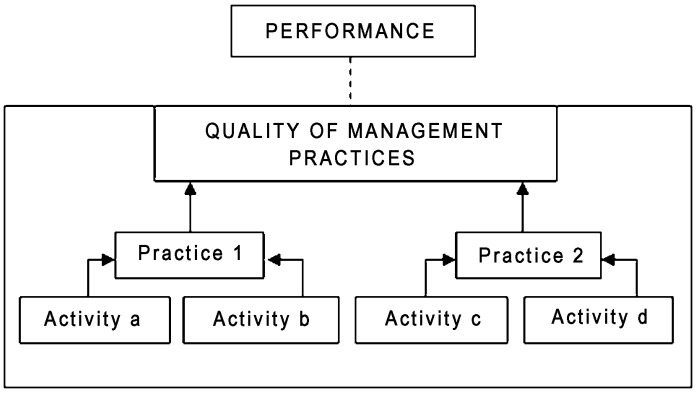

Fig. 1. The general structure of the study, including management activities, management practices, quality of management practices and performance.

2.3. Quality of management practices and application of complex technology

While early research has shown that higher quality of management practices is associated with better performance of a company, management innovation scholars posit that application of complex technological systems outright presupposes effective management practices [1,24]. Yet, again, empirical evidence is hard to come across. A study by Wang, Klein and Jiang discussed implementation of Enterprise Resource Planning (ERP) in Taiwan [25]. The limitation of this study was that a self-report instrument was administrated to companies' project managers, directly responsible for the technology project. Thus partiality bias could not be ruled out. Another study by Bloom, Sadun, and Van Reenen, conducted on panel data, suggested that US companies were more productive in using information technology (IT) partially due to their higher management and organizational capital compared to, for example, UK companies [26].

This study provides empirical evidence of a relationship between quality of management practices and application of complex technology by uniquely focusing on a highly complex industrial technology – a welding robot. In accordance with theoretical perspectives, the principal hypothesis of this study is as follows.

H2: *There exists a strong positive correlation between a company's quality of management practices and its capability to utilize complex automated equipment* (Fig. 2).

Prior studies in Estonia [6] have suggested a positive correlation between company size and the quality of management practices (defined in the frame of strategic planning). Such studies have alleged that smaller companies in Estonia tend to limit their horizon of planning with maximum of one year, while larger companies plan for 4 to 5 years. However, the same studies would state that the larger companies in the industry sector studied were foreign owned [6]. Next, it is argued that the foreign companies (such as subsidiaries of foreign corporations) were more likely to apply holistic enterprise management systems in order to achieve their goals more efficiently [6].

Fig. 2. Hypothetical relationship between quality of management practices and technological capability.

The above findings leave one to wonder whether the correlation was truly between the company size and quality of management practices, or was it that the foreign companies in Estonia had higher quality of management practices, they also tended to be dominantly large in their industry sector. Regardless of that, building on the principal hypothesis H2, this study states that high level of quality of management practices is required for utilizing complex automated equipment. Thus quality of management practices acts as a mediator between a company's technological capabilities and its other attributes. Such that capital ownership is related to a company's technological capabilities via the company's quality of management practices, and the size of the company in itself is insignificant in relation to the company's capability to utilize complex automated equipment. Based on this, the two additional hypotheses were formulated.

H3: *There is no significant relationship between a company size and its capability to utilize complex automated equipment*;

H4: *A significant relationship exists between capital ownership of a company and its capability to utilize complex automated equipment, mediated by the quality of management practices*.

Finally, the authors were intrigued whether tenure of full implementation of complex technology in itself improved a company's capability to utilize it. Such that simply having the technology in-house over time improved the company's capability to utilize it. The following hypothesis was formulated.

H5: *There is no significant relationship between tenure of full implementation of complex automated equipment and a company's capability to utilize it*.

3. METHOD

A pilot study was carried out among Estonian manufacturers which apply robot welding. A novel online survey instrument was used. An additional aim was to assess the workability of the survey instrument.

Management capabilities were measured via quality of management practices and activities as defined by Luthans and Lockwood and cited in [7], limited to the practices of an effective manager [8]. Eight out of the 12 Luthans and Lockwood management practices were operationalized: planning/coordinating, staffing, training/developing, decision making/problem solving, exchanging routine information, monitoring/controlling performance, motivating/reinforcing, and managing conflict. The practices, which were excluded due to not being attributes of an effective manager, were interacting with others (as defined in [7]) and socializing/politicking [8]. Processing paperwork was excluded because it is not a discriminative attribute – all managers perform some "general desk work" (see the full list of activities of processing paperwork on p. 259, [7]). Disciplining/punishing was excluded from the study because its activities potentially had opposite effects on the measured technological capability of a company [7]. "Enforcing rules and policies" and "giving feedback on negative performance" (p. 259, [7]) potentially

could have had a positive effect on employees', and thus the company's, performance. Such activities could, in fact, be part of daily motivating and reinforcing activities in a company. However, the other activities, such as "non-verbal glaring, harassment" and "demoting, firing, layoff" (p. 259, [7]) had the potential of having a negative effect on employees, thus affecting the company's technological capability. Thus the parameter of disciplining/punishing was regarded as inconclusive and excluded from the study.

Respondents were asked to assess the level of management practices in their company. For example, a sample question sounded "Please assess the level of decision-making and problem-solving in your company", followed by a detailed description of the activities in this management practice. The respondents were expected to mark one out of five levels of quality of the management practice ranging from "There are no such activities present in our company" to "Such activities are regular and documented. Results are publicly displayed on walls (information boards) for everyone to see".

Planning/coordinating was divided into long-term or strategic (defined by the time period longer than one year) planning and short-term (defined by the time period shorter than one year) planning. Thereby the total number of quality of management practices questions was nine.

In addition, respondents were requested to specify which of three management levels – top management, middle-management and/or frontline management – were actively practicing these management activities to see whether any of the management levels had a specific effect on the company's technological capability.

Company's technological capability was measured by a single right first time [23] (also referred to as "first-time-right") measure of the robot welding. Respondents were also able to mark one or more probable causes in a provided list, if right first time was less than 100% in their company.

The pilot instrument was administered via a freeware Kwik Surveys online application. An example of the screen view of a survey questionnaire as it was presented to a respondent is provided in Fig. 3.

Five Estonian manufacturing companies, classified at the 2-digit level of Estonian classification of Economic Activities (EMTAK) as codes 25, 28 and 31, which possessed in-house robot welding, were selected for the pilot study. The total number of such companies was estimated to be 50. Three aspects were considered in choosing companies for the study.

1. Subjective assessment (effective, average, ineffective) of the quality of management practices of the company by the members of the research group. To validate these assessments, two of the companies were personally visited by a member of the research group in the time period from the beginning of 2011 to February, 2012. Two other companies were assessed by another member of the research group, based on interactions with the companies since 2007 unrelated to this study. Secondary information (i.e. subjective assessments by individuals who were personally familiar with the company but

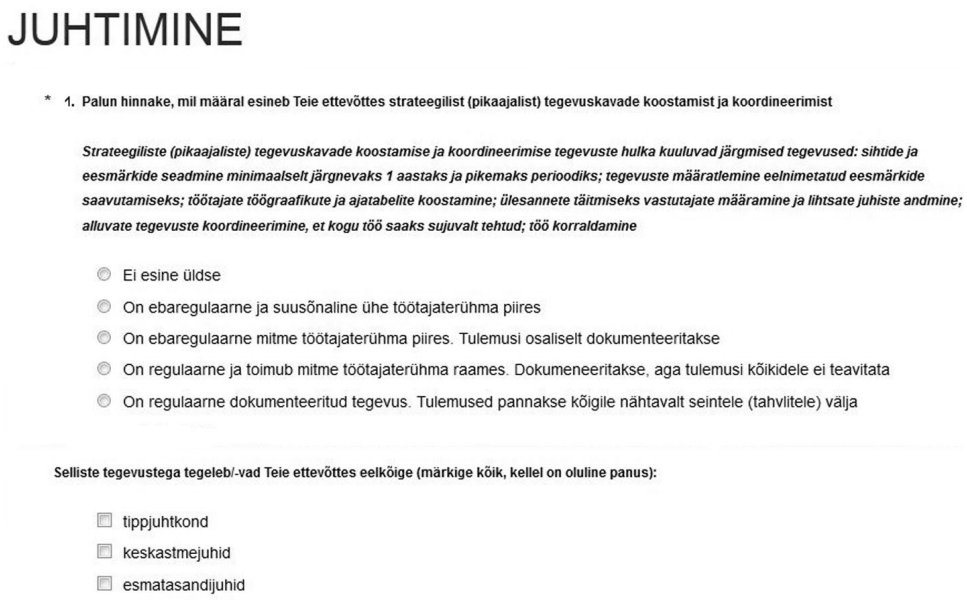

Fig. 3. An example of a screen view of a survey question to the respondent.

English translation of the screenview

MANAGEMENT PRACTICES

* 1. Please assess how much is there strategic (i.e. long-term) planning and coordinating applied in your company?

Activities included in strategic (i.e. long-term) planning and coordinating are the following: setting goals and objectives for a minimum of one year or a longer period; defining tasks needed to accomplish these goals; scheduling employees, timetables; assigning tasks and providing routine instructions; coordinating activities of different substitutes to keep work running smoothly; organizing the work.

- o There are no such activities present in our company;
- o Such activities are irregular, not documented and limited to only one group of employees
- o Such activities are regular among several groups of employees. The results are partially documented
- o Such activities are regular and involve several groups of employees. The results are documented but not made available to all
- o Such activities are regular and documented. Results are publicly displayed on walls (information boards) for everyone to see

Such activities are most actively practiced at the following levels of management at your company (mark all that apply):

□ top management
□ middle management
□ frontline supervisors

were not part of the research group) was utilized for the selection of the fifth company. As a result, companies at diverse levels of quality of management practices, ranging from effective to ineffective (subjective assessments), were selected. It is important to point out that the members of the research group had no knowledge of the value of the other variable, right first time of the robot welding, at these companies.

2. Subjective assessment of the complexity of the products processed by robot welding (simple, complex). Three of the selected companies were assessed to process complex products (whole modules of machine-building products) and two of the companies were assessed to process simple products (with the welding process consisting of 1 to 2 simple welding operations) by robot welding.
3. Size of the company. The aim was to have both "small" and "large" companies in the sample. As a result, the sample contained 1 company with 10 to 49 employees, 3 companies with 50 to 249 employees, and 1 company with more than 250 employees.

In summary, the sample of the pilot study was balanced in terms of the quality of management practices of the companies, simplicity or complexity of products processed by robot welding, and size of the company. It is important to emphasize that the members of the research group were not currently employed nor had ever been employed by or belonged or had been belonged among the owners the companies studied.

Links to the survey instrument were sent to one top or middle manager (e.g. General Manager, Quality Manager, or Production Manager) in each company.

Analysis of the results of the survey was conducted in the following manner. First, an analysis of variance (ANOVA) was utilized in order to determine whether (1) different management levels (hypotheses H1a and H1b) or (2) general variables, such as company size (H3), capital ownership (H4) or tenure of full implementation of robot welding (H5) showed statistically significant dependence on the company's technological capability. Next, linear correlation coefficient was determined between the total quality of management (measured as the sum of category responses) and the technological capability measure (right first time) to assess the principal hypothesis H2. Last, frequency analysis was carried out for determinants of the right first time parameter.

In addition, it was assessed whether the respondents found the survey instrument easy to fill in, or should changes be made to it in future studies.

4. RESULTS

Results of ANOVA suggest that there is no reason to support the hypotheses H1a and H1b about the company's management levels' impact to its technological capabilities on the significance level α being 0.05. In the frame of the nine management practices, asked from the respondents, there is no evidence

about statistically significant dependencies. The within-group degree of freedom for this sample is 3 and the one between groups is 1. Based on this, ANOVA provided the critical values for F-statistic in the frame of nine management practices as follows $F(3,1) = 9.55$; $F(3,1) = 2.57$; $F(3,1) = 0.81$; $F(3,1) = 8.73$; $F(3,1) = 2.24$; $F(3,1) = 2.72$; $F(3,1) = 0.23$; $F(3,1) = 4.20$; $F(3,1) = 4.20$. Corresponding probabilities quantifying the strength that hypotheses H1a and H1b were true (the *p*-values) resulted in values as $F(9.55,3,1) = 0.23$; $F(2.57,3,1) = 0.42$; $F(0.81,3,1) = 0.65$; $F(8.73,3,1) = 0.24$; $F(2.24,3,1) = 0.49$; $F(2.72,3,1) = 0.41$; $F(0.23,3,1) = 0.87$; $F(4.20,3,1) = 0.34$; $F(4.20,3,1) = 0.34$. Considering that the calculated *p*-values remain above the significance of 0.05 for all nine management practices, there is no reason to support either hypothesis H1a or H1b.

However, correlation coefficient of 0.74 supports the hypothesis H2 about significant positive dependency between the quality of management practices and a company's capability to utilize complex automated equipment. Thus an assumption can be made that higher level of quality of management practices allows to predict presence of company's higher technological capabilities.

In addition, statistically significant dependencies were not evident between the company size, capital ownership and tenure of full implementation of robot welding and technological capability at significance level α being 0.05 ($F(3,1) = 3.27$). Hence this study provides evidence to support the hypothesis H3 (there is no significant relationship between company size and its capability to utilize complex automated equipment) and H5 (there is no significant relationship between tenure of full implementation of complex automated equipment and the company's capability to utilize it), but not H4 (a significant relationship exists between capital ownership of the company and its capability to utilize complex automated equipment).

The most frequent responses for causes of poor right first time were missing jigs (3), poor quality of the material (2), and missing a competent operator for the robot (2).

Respondents found the survey instrument easy to use. More nominal range options or the actual right first time measure could be asked in next studies for a more reliable correlation.

5. CONCLUSIONS

A study was carried out to investigate the relationship between companies' management and technological capabilities. Management capabilities were defined as management practices and operationalized via Luthans and Lockwood management practices and activities [7]. The companies' technological capability was measured by the single right first time measure on the companies' welding robot(s).

The results of the study supported the primary hypothesis that there is a strong positive correlation (correlation coefficient of 0.74) between the company's

quality of management practices and it's capability to apply a complex automated system of robot welding.

Secondary hypotheses about companies' management levels impact on their technological capabilities were not supported at significance level α being 0.05. Also existence of statistically significant dependencies between the companies' general variables (company size, capital ownership, tenure of full implementation of robot welding) and technological capabilities were not supported (at significance level α being 0.05).

Respondents found the survey instrument easy to use.

6. DISCUSSION

Management innovation scholars over the last decade and quality management authorities over several past decades have indicated that companies need effective management practices in order to utilize complex technological systems. However, empirical evidence for a relationship between companies' management and technological capabilities has been lacking. This study plugs an important gap in empirical evidence describing the relationship between companies' management capabilities, defined via quality of the management practices, and application of complex automated systems.

The primary limitation of this pilot study was the small sample size (five companies). There was strong support to the principal hypothesis of the study; however, additional hypotheses, allowing a more thorough view into the issue being investigated, were not statistically supported. Yet, evidence could be found in data analysis that with a more comprehensive sample, statistically significant relationships could be uncovered between companies' management levels and their technological capability and between the companies' general variables (such as company size, capital ownership and tenure of full implementation of robot welding) and their technological capability. The total population of companies, owning robot welding technology in-house was estimated to be 50 in Estonia. Thus the sample size of five companies, making up about 10% of the population, was sufficient to form an argument that the results of the pilot study were relevant. The strong support to the principal hypothesis of the pilot study encourages continuing this line of research. The total number of companies in Estonia, which might be influenced by this line of research was about 1000 in 2011 [27]. These were companies with similar profiles to these of the participant companies in this study – i.e. number of employees 10 and above, and manufacturing in industry sectors where robot welding could be a viable technological option.

Other levels of technological complexity could be investigated with the same methodology to see whether there exists a level of complexity at which quality of management practices has no statistically significant influence on the utilization of such technology.

Discussions with practitioners and scholars have surfaced the question whether complexity of products had a significant impact on companies' ability to utilize technology effectively and efficiently. Thus the complexity of products could be incorporated as a moderating parameter in the investigation of the relationship between the quality of management practices and companies' ability to utilize complex technology. Quality management literature, as well as casual observations in different companies, has indicated that the moderating effect of the complexity of products might be insignificant. In other words, a low management capability company would not be able to effectively and efficiently produce the most elementary of products, regardless of applying complex technology in production, while a high management capability company can effectively and efficiently produce any complexity of products utilizing any competitive technology.

A statistical sample would also allow to fully validate the survey instrument. Covariance is expected to be present among some of the nine non-parametric management practices variables (such as training/developing and motivating/ reinforcing). No covariance is expected to be present among other variables of the survey instrument, except, perhaps, in the case of Estonia, a covariance between company size and capital ownership.

The survey was administered to only one top or middle manager (e.g. General Manager, Quality Manager, or Production Manager) in each respondent company. While carefully chosen to be knowledgeable, experienced, and objective in their responses, the perceptions of the application of management practices in a company may vary among different managers, functions, levels of management, etc. It should be considered to enlarge the number of respondents per company in future studies to form a more accurate assessment of the application of management practices, at least in medium and large companies. The location of the respondents (geographically as well as in the organizational structure of the company) should, however, be chosen so that they are assessing the conditions surrounding the technology under investigation (such as, to give an exaggerated example, an administrative assistant in Taiwan might not be familiar with the respective conditions when assessing a manufacturing site in Estonia).

Investigating the reported causes for a poor right first time in robot welding (missing jigs, poor quality of material, and missing a competent operator for the robot), these evidently belong to the top management's responsibilities in a typical company in the country where the study was carried out. This is surprising as the top management is typically also responsible for the decision to invest in a complex technology. Is the current situation a result of poor planning (for the investment) or of poor communication for corrective action? Once again, a more comprehensive study would allow a more thorough research into the issues leading to poor utilization of the technology in companies.

Finally, it would be interesting to carry out this study in other countries and nations to see whether management practices have a different relationship with technological capabilities there.

In short, a full-scale study as well as additional studies would provide further information regarding issues impacting utilizing complex technology in companies by uncovering significant relationships potentially concealed in the pilot study, and by expanding a proven methodology to other aspects of technological complexity and other countries.

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Juhtimisvõimekus ja keeruka automatiseeritud tehnoloogia rakendamine ettevõtetes

Kadri Kristjuhan, Ergo Metsla ja Hannes Ling

Paljud juhtimisteadlased on väitnud, et keerukate automatiseeritud tehnoloogiate tulemuslikuks rakendamiseks on vajalik ettevõtte efektiivne juhtimine. Ent on vähe uurimusi, mis tegelevad seosega ettevõtte juhtimise ja selle tehnoloogilise võimekuse vahel. Käesolev uurimus püüab seda lünka osaliselt täita. Uurimuses osalesid robotkeevitustehnoloogiat omavad Eesti ettevõtted. Tuvastati tugev korrelatsioon (korrelatsioonikoefitsient 0,74) ettevõtete juhtimisvõimekuse ja keeruka automatiseeritud tehnoloogia rakendamise tulemuslikkuse vahel. Uurimuse käigus töötati välja küsimustik ettevõtte juhtimis- ja tehnoloogilise võimekuse hindamiseks.