The impact of innovation and organizational factors on APS adoption: Evidence from the Dutch discrete parts industry

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The impact of innovation and organizational factors on APS adoption: Evidence from the Dutch discrete parts industry[°]

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Abstract

Advanced Planning and Scheduling (APS) systems have gained renewed interest from academics and practitioners. However, literature on APS adoption is scant. This study explores the impact of organizational and innovation related factors on the adoption of APS systems from a factors approach. The results from our field survey of 136 Dutch discrete manufacturing firms, show that management support, cost of purchase, number of end-products, and the value that firms attach to other users' opinions are key-factors that directly influence the adoption of APS systems. In addition, professionalism, external communications, and innovation experience indirectly influence APS adoption.

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1 Introduction

Due to the globalization and technological developments, in particular in information and communication technology, market demands are changing rapidly resulting in increased environmental and organizational uncertainty. This influences the production planning and control task characteristics, thereby favoring flexible and intelligent production and planning and control technologies [8]. One strategy to cope with uncertainty is the adoption of Advanced Planning and Scheduling (APS) systems to implement intelligent manufacturing planning and control systems that simultaneously support material coordination and planning and scheduling of scarce resource capacity [42].

Meyr *et al.* [33] identify a common thread of most commercial APS systems. APS systems generally encompass top-down intelligent functionality for strategic, tactical and operational issues, such as Strategic Network Planning, Master Planning, Demand Planning, Demand Fulfillment and Availability To Promise, Master Planning, Distribution Planning, Transport Planning, Production Planning, Scheduling, and Material Requirements Planning. Hence, these APS systems are centralized control systems. Furthermore, APS systems that provide all this functionality for diverse industries are generally classified as high-end APS systems. Global high-end APS vendors are for example I2, Manugistics, and Aspen Technology. In addition, most leading ERP vendors, such as SAP and Baan, also have an advanced planning and scheduling application. As the objective and scope of the larger ERP vendors primarily is to cross-sell APS solutions to their installed base, i.e. especially multinationals in the semi-process industry, the automotive industry and the aerospace industry, these ERP vendors generally do not have a specific industry focus.

Regional players, such as KIRAN and ROI Systems in the US and Quintiq, Ortec, and OM Partners in Northern Europe focus more on industry-specific APS solutions. They generally offer less functionality than global high-end APS vendors. For the discrete parts manufacturing industry, for instance, regional vendors generally offer APS systems that emphasize lot-sizing, order acceptance, production planning and detailed scheduling functionality where the manufacturing system of the user is the centre of attention, i.e. internal tactical and operational planning and scheduling functionalities. These APS systems are generally indicated as mid-end systems. In addition, vendors that only offer one or more stand-alone functionalities, for instance an electronic graphical scheduling system (DSS), are generally indicated as vendors of low-end APS systems. In this study, however, we primarily focus on mid-end and low-end APS systems aimed for the discrete parts manufacturing industry, where we define an APS to be a software system with at least a graphical interface and intelligent decision support functionality based on Operations Research or Artificial Intelligence models for manufacturing planning and scheduling purposes. Hence, MS-Project, for instance, is not an APS system.

Much research on APS systems focuses on algorithms behind the screen of these systems [11,33,51]. Less research is conducted on APS adoption issues from a factors approach. Nevertheless, any technology adoption is best understood by analyzing and understanding the various contextual factors both from within and from the external environment that resulted in adoption of the technology [8,26,38]. The factors approach attempts to identify static factors that influence the adoption of a technological innovation.

The dearth of relevant APS adoption publications is partly because APS is a relatively new technology with a moderate adoption rate. Therefore, the nature of any study on APS adoption issues can be only defined exploratory. In this paper, however, we investigate the impact of innovation specific and organizational factors on APS adoption. Hence, this paper addresses the questions "what is the state-of-the-art of advanced planning and scheduling within the discrete parts manufacturing industry"; and "what is the impact of innovation and organizational factors on APS adoption?" The main contribution of this paper is a model that embeds organizational and innovation specific characteristics for APS adoption into the general innovation adoption theory.

The outline of this paper is as follows. In section 2, we briefly discuss an APS adoption meta-model, in which we distinguish innovation specific characteristics and organizational characteristics. In section 3, we discuss the various propositions in more detail. In section 4, we discuss the research method and the development of a questionnaire. In section 5, we provide operational definitions of the constructs. In section 6, we present the results of non-parametric statistical analysis for associations between the innovation and organizational constructs and APS adoption. Furthermore, we examine for spurious relationships. These analyses result in two conceptual models: one basic conceptual APS adoption model without any spurious relationships, and one extended model in which possible spurious relationships are included. In section 7, we apply structural equations modeling to analyze the direction of the relationships between the constructs displayed in both conceptual models. Finally, in section 8, we end this paper with a brief discussion of the findings and the managerial implications, as well as conclusions and directions for further research.

2 An APS adoption meta-model

To our best knowledge, we are not aware of any 'factors' studies on APS adoption. As a result, the theory discussed in this section is adapted from strongly related work, *e.g.* adoption and implementation research of Enterprise Resource Planning systems [4,10,27], Advanced Manufacturing Technologies [2,40,49] and Computer Aided Manufacturing [17].

Basic work in the area of innovation research is the work of Rogers [39] who describes diffusion of an innovation as the process by which an innovation is communicated through certain channels over time among the members of a social system. It is generally assumed that this theory also holds for organizations as a social system on its own. Furthermore, Rogers [39] states that the rate of adoption, i.e. the relative speed with which an innovation is adopted, depends on the opinion of the organization about the relative advantage, the compatibility, the complexity, the trialability and the observability as characteristics of the innovation. In addition, a review by Kwon and Zmud [26] of the literature on the relationship of organizational innovation and information systems implementation identifies a number of variables that contribute to the successful introduction of a technological innovation in an organization. These variables are categorized into individual variables, organizational variables, innovation variables, and task-related variables, where the contribution of each variable to the successful implementation of the innovation depends on the specific situation. As the adoption and implementation of APS systems exceeds individual decision-making and individual task-related activities, we primarily consider the *innovation characteristics* and the *organization characteristics* as important.

Innovation characteristics In a meta-analysis of the innovation characteristics literature, Tornatzky and Klein [44] identify ten important innovation characteristics: compatibility, relative advantage, complexity, cost, communicability, divisibility, profitability, social approval, trialability and observability. We also use these innovation characteristics except for *profitability* (since it coincides with relative advantage), *social approval* (since we expect it to have no relevance for APS adoption), communicability (since it corresponds to observability), and *divisibility* (since it is closely related to trialabilty—i.e. an innovation that is not divisible has limited trialability). In addition, we include some *new* innovation related characteristics: adaptation [41], other users' opinions [14], and vendor support [17,20]. McGowan and Madey [32] used vendor support as an environmental indicator, but we see vendor support as an innovation characteristic, since the degree of vendor support can vary from supplier to supplier.

Organizational characteristics In a meta-analysis of the adoption of innovations in organizations, Damanpour [9] identifies positive relationships between innovation and specialization, functional differentiation, professionalism, managerial attitude toward change, technical knowledge resources, administrative intensity, slack resources, external communication and internal communication.

We do not include all of these characteristics of organizational innovation in our research because they are either more applicable to the adoption of an innovation by an individual (*e.g.* managerial tenure), or enveloped by other characteristics. We omit technical knowledge resources since it coincides with professionalism. The latter also comprises the educational level of employees [3,28].

Furthermore, as they are frequently mentioned in other studies, we add the following organizational characteristics into our APS adoption model: innovation experience [17,19] and size [1,2,23,28,43,50]. In summary, we decided to use the following organizational characteristics: ERP usage, external communication, functional differentiation, innovation experience, internal communication, management support, size, and professionalism.

We also investigated possible relations between APS adoption and environmental characteristics such as economical condition, market demand characteristics and the competitive position of respondents, but we found no significant relations between these variables. As a result, we only discuss the possible relationships between the selected characteristics in the categories innovation and organization, and the decision to adopt an APS system. This meta-proposition is displayed as an APS adoption meta-model in Fig. 1.

-- Insert Fig. 1 about here --

3 Detailing the propositions

In this section, we discuss a number of propositions to state the expected directions of the relationships between the innovation and organizational characteristics and APS adoption as displayed in the APS adoption meta-model.

3.1 Innovation characteristics

Compatibility Compatibility is the degree to which an innovation is perceived as consistent with the existing values, past experiences and needs of potential adopters [44]. The perceived compatibility of an innovation is positively related to its rate of adoption [39]. Furthermore, Kwon and Zmud [26] state that compatibility is often cited to determine the success of an innovation. Hence, we expect to find a positive relationship between compatibility and APS adoption.

PROPOSITION 1 Compatibility is positively related to APS adoption.

Complexity Complexity is the degree to which an innovation is perceived as relatively difficult to understand and to use. In a study on client/server technology adoption, Prakash [36] states that organizations may be unwilling to adopt an innovation if they consider it beyond their ability to comprehend and use. In addition, Venkatesh and Davis [46] conclude that perceived ease of use has a positive influence on increasing the user acceptance of a technological innovation. Hence, complexity is negatively related to innovation [17,26,39,44]. We, therefore, expect to find a negative relationship between complexity and APS adoption

PROPOSITION 2 Complexity is negatively related to APS adoption.

Adaptation Adaptation is the degree to which an innovation can easily be adapted for its future and possibly changing working environment. Lack of adaptation of Enterprise Resource Planning systems is frequently cited as a pitfall of implementation projects [10,27]. We postulate that if an APS system can easily be adapted into an organization's specific environment, it has a higher rate of adoption. Hence, we expect to find a positive relationship between adaptation and APS adoption.

PROPOSITION 3 Adaptation is positively related to APS adoption.

Observability Observability is the degree to which future benefits of an innovation can be made easily visible to organizational members. Observability of an innovation is positively related to its rate of adoption [39,46]. Hence, we expect to find a positive relationship between observability and APS adoption.

PROPOSITION 4 Observability is positively related to APS adoption.

Other users' opinions Other users' opinions is the degree to which a potential adopting organization attaches importance to the opinions of other APS adopters [14]. The experiences others gained while adopting an APS system can help an organization to overcome barriers in adopting and implementing an APS system [39]. Hence, we expect to find a positive relationship between other users' opinions and APS adoption.

Proposition 5 Other users' opinions is positively related to APS adoption.

Relative advantage Relative advantage is the degree to which an innovation is perceived as better than the idea it supersedes. A perception of relative advantage of the innovation over existing or alternate products or processes has been found to be positively related to adoption and implementation [26,37,39,44]. In addition, McGowan and Madey [32] find a positive relationship between relative advantage and the extent of EDI implementation, which is consistent with the research of Ettlie and Vellenga [15] on the adoption of transportation related innovations. Prakash [36] found evidence that relative advantage is a predictor of successful client/server technology adoption. Hence, we expect to find a positive relationship between relative advantage and APS adoption.

Proposition 6 Relative advantage is positively related to APS adoption.

Total cost of ownership The costs of an innovation not only consist of the initial cost of purchasing but also comprise the cost of implementation and maintenance. Cost is generally assumed to be negatively related to the adoption and implementation of an innovation [44]. The higher the costs of an innovation, the more likely it will not quickly be adopted and implemented, due to increasing chance on low return on investment. This relationship is, of course, strengthened by uncertainty about future revenues because of the innovation. In addition, Bingi *et al.* [4] state that uncertainty of future implementation costs hinders adoption. Furthermore, the initial cost of procurement is considered to be negatively related to the chances of successful adoption [17]. Hence, we expect to find a negative relationship between total cost of ownership and APS adoption.

Proposition 7 Total cost of ownership is negatively related to APS adoption.

Trialability Trialability is the degree to which an innovation may be experimented with prior to definite purchase. The trialability of an innovation is positively related to its rate of adoption [39]. This is confirmed by Prakash [36] in that trialability is a predictor of successful adoption of client/server technology in organizations. Hence, we expect to find a positive relationship between trialability and APS adoption.

Proposition 8 Trialability is positively related to APS adoption.

Vendor support Vendor support is the degree to which the vendor of an innovation gives support during the decision phase and during the implementation process. Vendor support is positively related to adoption and implementation, because support given by the vendor will help to reduce uncertainty in the innovation process. Ettlie [14] concludes that the vendor-user relationship is an important determinant of successful implementation of manufacturing technologies. McGowan and Madey [32] state hat vendor support can help an organization make greater use of EDI software. Hence, we expect to find a positive relationship between vendor support and APS adoption.

PROPOSITION 9 Vendor support is positively related to APS adoption.

3.2 Organizational characteristics

ERP usage ERP systems have no intelligent planning and scheduling functionality [42,51], albeit some ERP vendors offer their customers APS add-ons. What is more, ERP caters for the data required by the APS system. Hence, we expect to find a positive relationship between the usage of an ERP system and APS adoption.

PROPOSITION 10 ERP usage is positively related to APS adoption.

External communication External communication indicates the degree to which the organization is in active contact with its environment. Rogers [39] states that earlier adopters have more social participation, are more highly connected in the interpersonal networks of their system, are more cosmopolite, have more 'change agent' contact, greater exposure to mass media channels, greater exposure to interpersonal communication channels and engage in more active information seeking. Organizations are continually identifying problems and considering alternative solutions, attempting to match solutions to problems. Organizations frequently scan the environment looking for solutions or to see how other organizations have dealt with similar problems. Organizations that engage more in this type of activity are more likely to find solutions to their problems [5,9,32,50]. Hence, we expect to find a positive relationship between external communication and APS adoption.

PROPOSITION 11 External communication is positively related to APS adoption.

Functional differentiation Functional differentiation represents the degree to which an organization is divided into different departments. Baldridge and Burnham [1] conclude that complex organizations are more likely to adopt innovations than simple organizations, since differentiation produces specialists searching for new solutions to the 'task demands' within their specialized realms. This is confirmed by Kimberly and Evanisko [23] and McGowan and Madey [32].

Furthermore, Kwon and Zmud [26] state that there is a positive relationship between functional differentiation and the adoption of technological innovations.

In contrast, there are also researchers who suggest a negative relationship between functional differentiation and innovation. Grover *et al.* [20], for instance, suggest that adopters of telecommunication initiatives are less functionally differentiated so they can react to environmental uncertainties in a pro-active manner. Damanpour [9] argues that low functional differentiation permits openness, which encourages new ideas and innovations. However, we initially hypothesize to find a positive relationship between functional differentiation and APS adoption.

PROPOSITION 12 Functional differentiation is positively related to APS adoption.

Innovation experience Innovation experience is the degree to which an organization has successfully adopted innovations in the past. Gerwin [17] states that the adoption of an innovation is greatly facilitated by previous successful adoptions of technological innovations. Problem solving experience gained from these previous adoptions and implementations helps to reduce difficulties in adopting and implementing future innovations [19,30]. Hence, we expect to find a positive relationship between innovation experience and APS adoption.

PROPOSITION 13 Innovation experience is positively related to APS adoption.

Internal communication Internal communication indicates the degree to which the organization internally communicates between different departments. According to Brancheau and Wetherbe [5], potential adopters of innovations strongly favor the use of internal/interpersonal channels of communication. Internal communication facilitates dispersion of ideas on the innovation within the organization. In addition, Bingi *et al.* [4] state that implementing an ERP system requires negotiation between departments. We postulate that this also holds for APS systems. Hence, we expect to find a positive relationship between internal communication and APS adoption.

PROPOSITION 14 Internal communication is positively related to APS adoption.

Management support Management support is the degree to which management supports the entire process of the adoption and the implementation of innovations, hence management support is positively related to adoption of an innovation [1,9,32]. Premkumar *et al.* [37] states that management that recognizes strategic opportunities from the innovation would be more willing to facilitate adoption and implementation. This is confirmed by the study of Thong and Yap [43] in which they state that organizations that have a management with positive attitude towards an innovation are more likely to adopt the innovation. Hence, we expect to find a positive relationship between APS adoption and management support.

PROPOSITION 15 Management support is positively related to APS adoption.

Size The size of an organization is positively related to the adoption and extent of implementation of an innovation [23,28,32]. On one hand, 'size' enables innovations as it is relatively easy to allocate required resources [37,49]. In addition, Thong en Yap [43] argue that small businesses face more barriers to adopt innovations because their inability to allocate sufficient resources. On the other hand, size induces the need to innovate, for example to cope with coordination and control problems [1]. Hence, we expect to find a positive relationship between APS adoption and size.

PROPOSITION 16 Size is positively related to APS adoption.

Professionalism Professionalism is the degree to which an organization is knowledgeable about an innovation and required skills and processes. Professionalism is positively related to the adoption of technical innovations [3,9,32]. Chew *et al.* [7] conclude that know-how and know-why is needed for successful implementation of new technologies. According to several studies, early adopters are more highly educated or have a greater knowledge of innovations [5,23,39,43]. In addition, Zhao and Co [49] studied the adoption and implementation of advanced manufacturing technologies and found technical knowledge to be a significant determinant of successful use of advanced manufacturing technology. Hence, we expect to find a positive relationship between APS adoption and professionalism.

PROPOSITION 17 Professionalism is positively related to APS adoption.

4 Research method

4.1 Population and sample selection

The data for this study were collected through a comprehensive mail survey among Dutch manufacturing firms listed in a commercial database for manufacturing firms with more than 20 employees. The manufacturing firms selected belonged to International Standard Industrial Classification of all Economic Activities (ISIC) codes 17, 19–21, and 27–36. Hence, these selected firms are from discrete parts manufacturing industries as they involve the manufacture of discrete products, primarily of metal and non-metal fabrication, and exclude all process industries.

There are in total 20,625 Dutch firms listed under the ISIC codes under study. Note that Dutch discrete industrial firms are notably small and medium sized enterprises (SME). According to the research agency EIM B.V. [ii] there are only 5020 Dutch firms with more than 20 employees; i.e. 75% of the Dutch firms (with above mentioned ISIC codes) have less than 20 employees. Hence, the population under study is 5020 firms. We phoned 600 of these firms to inquire their willingness to participate in this research, where we primarily asked for an Operations Management employee that was responsible for renewal and innovation of planning and control procedures and systems. Almost 47% of the firms agreed to participate, so a package containing a cover letter, a questionnaire and a pre-paid reply envelope, was sent to 279 firms. In the cover letter, the purpose and necessity of this study were explained, the term APS system was defined, the design of the questionnaire was explained, and the respondents were assured of confidentiality. The definition we used for an APS system was: 'An APS system is a software system with at least a graphical interface and intelligent decision support functionality based on Operations Research or Artificial Intelligence models for manufacturing planning purposes and scheduling with the purpose of creating a planning as good as possible'. 103 respondents returned the questionnaire within 6 weeks, so there were 176 initial non-respondents. We then decided to phone the firms of which we suspected not to have returned the questionnaire to inquire whether they had sent back the questionnaire yet. If not, we asked again to still fill it out and return it. 27 non-respondents could not be re-contacted, or were not willing to be contacted by phone again. 48 firms said that, at second thought, they would not fill out the questionnaire, while 14 firms said they already had sent it back (this could be true because respondents were offered the option to fill out the questionnaire anonymously) and 87 firms indicated that they still would send it back. From this group of 87 firms, we had to resend the questionnaire to 59 firms because they had misplaced the questionnaire. In this second round, 41 firms eventually returned the questionnaire.

In all, there were 144 questionnaires returned. However, responses from eight firms were excluded from the final sample because these firms did not fulfill the criterion of a discrete parts manufacturer, or the package was sent back as 'undeliverable'. Hence, we have 136 useful responses and a final response rate of 22.6% of the original sample, which is acceptably high compared to other mail surveys reported in literature [25,31].

4.2 Respondents and response bias

To estimate response bias we compare the distribution of the organizations in the sample over the various sectors within the discrete manufacturing industry and the distribution of the number of employees of the organizations in the sample with these distributions in the whole population. Therefore, we use the following two indicators: ‘the total number of employees of the organization’, and ‘the sector the organization operates in’. To check whether the respondents are indeed representatives of our target-respondents we use the indicator ‘respondent’s function in the organization’.

--Insert Table 1 about here—

Representativeness of the sample We first list the sectors in which the responding firms are active; see Table 1. From this table, we note that the majority of firms is operating in the sector ‘basic metals and fabricated metal products’. We note that almost 90% of the respondents were able to list their firm in one of the sectors. If the ISIC classification for a firm could not be determined, because the respondents failed to identify their firms, the firm was classified as ‘other’. Respondents from firms in the process industry were omitted immediately.

From the comparison of the distribution of the different sectors of the 136 responding firms, and this distribution of the entire population (according to EIM B.V. [i]), we note that the sector ‘basic metals and fabricated metal products’ is a little overrepresented in our sample. Since this is the most important group in the entire population, we do not expect this to cause problems with generalizability. In addition, comparing the distribution of the number of employees of the organizations in the sample with the distribution of the number of employees of the organizations in the entire population does not reveal bias.

Respondents With respect to the type of respondent, we conclude that at least 45% were operations managers. As the letter that accompanied the questionnaire primarily asked the survey be completed by an Operations Management employee responsible for renewal and innovation of planning procedures and systems, some firms decided that this responsibility lied with the general manager, the IT manager, or even an operational IT employee in case of the smaller firms. In addition, a brief investigation by telephone indicated that some operations managers passed the survey on to their responsible specialist or planner. As a result, 13% of the respondents are operational Operations Management specialists or planners; see Table 2.

--Insert Table 2 about here—

Non-response bias As we actively re-phoned non-/late-respondents to fill out and return the questionnaire, we might as well consider the group of late-respondents as equivalent of the group of non-respondents for purpose of non-response bias tests. ANOVA analysis on the 30% earliest respondents with the 30% latest respondents with respect to the number of employees and the turnover gave no reason to assume any form of non-response bias.

APS and ERP validity and APS adoption bias A reportedly adopted APS which turns out not to be a true APS undoubtedly harms the results of our analysis. To anticipate on this problem, we asked the respondent to indicate the vendor's name, which gives us the opportunity to check whether the system really is an APS system. A similar procedure is performed in case of ERP systems. Based on the outcome we concluded that six organizations had not implemented a real APS system. Note that one respondent did not fill-out this option, hence is useless for this study. These organizations are removed from the sample for statistical analysis of our hypotheses, but not for construct reliability analysis.

APS adoption can also be a cause of response bias, since some questions may not be answered by all respondents but just by the APS adopters or non-adopters. Hence, we have 129 responses, from which 19 have adopted a real APS system, which is 14.7% of the respondents. We calculated the percentage of APS adopters of the respondents for all questions separately, and found that these percentages varied from 14.1% to 18.1%. As a result, we conclude that APS adoption does not cause any response bias with respect to APS adopters and non-adopters.

4.3 Questionnaire development

In this study, we use constructs that cannot be measured directly (*e.g.* latent variables); hence, they have to be operationally defined, by one or more observed indicators [18]. Content validation was assessed through the theoretical basis for the indicators in literature, and through pre-testing of the preliminary draft of the questionnaire in five organizations that have adopted APS systems. Furthermore, We followed the guidelines for writing questions presented by Fink and Kosecoff [16]. For all questions in the questionnaire, we used 5-point scales as much as possible to facilitate the use of statistical analysis without recoding. Since we aim to prevent the situation that a respondent decides to not fill out an answer or guess an answer because he does not know the answer, we decide to thriftily include the option ‘Not known’. Note, however, that this option also provides an easy escape for more difficult questions. The same holds for the option ‘Not applicable’, which we also occasionally use. Furthermore, we occasionally allow the respondents to give multiple answers. Finally, we developed a comprehensive questionnaire of 74 indicators, representing all constructs and to check for response bias and authenticity of APS and ERP adoption. We divide the questionnaire into six parts, each concerned with a different subject. The first four parts are used to profile the respondents; the first part contains questions regarding general information about the firm, the second part contains questions about the market in which the firm operates, the third part contains questions about the manufacturing processes in the firm, and the fourth part contains questions about the way of planning in the firm. In the fifth part, the respondent can indicate which arguments play a role in the decision to adopt an APS system. In the sixth part, the respondent has to fill out in which way he/she agrees with a number of propositions.

5 Operational definitions

Most constructs in this study are abstractions in the theoretical domain. As these constructs are not directly observable, we have to provide operational definitions that are observable. All operational definitions, or indicators, are transformed into single questions or statements in the questionnaire. To increase reliability, existing indicators previously reported in the literature were used as much as possible.

To test the correlation among the indicators of a construct, usually, Pearson’s correlation coefficient, which is a measure of linear association between two variables, was computed. The absolute value of this correlation coefficient indicates the strength of the linear relationship between the indicators, with larger absolute values indicating stronger relationships. The sign of the coefficient indicates the direction of the relationship. However, Pearson’s correlation coefficient assumes two interval or ratio-scaled indicators. As our multiple-indicator constructs consist of indicators with an ordinal scale, we test for correlation among the indicators of each construct by calculating Spearman’s ρ (or Spearman’s rank correlation coefficient) that is calculated by applying the Pearson correlation formula to the ranks of the data rather than to the actual data. For ordinal-scaled indicators, there is no numerical test of internal reliability, such as Cronbach’s alpha for interval scaled indicators. However, since the significance levels of all correlation coefficients appeared to be the same for all indicators treated as ordinal-scaled (as measured by Spearman’s ρ) and Likert-type scales are frequently considered to represent underlying continuous variables, we only present reliability analysis based on Pearson correlation coefficients and Cronbach's alpha to evaluate internal reliability of operational definitions. That is, we accept operational definitions of a multi-indicator scale if the value of Cronbach's alpha is higher than 0.60 [35].

5.1 Indicators for the innovation constructs

Compatibility *Compatibility* is used in many studies on technological innovations. Operationalizations frequently used by researchers are: 'compatibility of the innovation with existing systems and infrastructure' [19,32,40], 'compatibility with existing practices of the adopter' [34,44], and 'compatibility with the values and believes or norms of the adopter' [19,44]. In addition, Tornatzky and Klein [44] also include an indicator that measures to what extent the innovation differs from former work methods. Hence, we operationalize *compatibility* by: 1) 'the degree of compatibility of an APS system with the existing firm's culture', and 2) 'the degree of compatibility of an APS system with the current way of planning'. With a value of Cronbach's alpha of .6451 this operationalization is sufficiently reliable; see Table 3.

--Insert Table 3 about here—

Complexity *Complexity* is another construct that has frequently been used in previous studies [19,34,46]. Occasionally however, it is referred to as *ease of use* with corresponding indicators [34,46]. In addition, Grover [19] uses the indicators 'we believe that the system is complex to use', and 'we believe that system development is a complex process'. As a result, we distinguish two categories from these indicators; *understanding* the innovation and *using* the innovation. We, therefore, operationalize *complexity* by the indicators 1) 'the ease to understand an APS system', and 2) 'the ease to use an APS system'. Given the value of Cronbach's alpha of 0.7795, this operationalization is sufficiently reliable; see Table 4.

--Insert Table 4 about here--

Adaptation We operationalize the *adaptation* of an APS system by 1) 'the ease to adapt an APS system to changing circumstances', 2) 'the possibility to run what-if analysis with an APS system', and 3) 'the possibility to adapt the results generated by an APS system by hand'. Given the value of Cronbach's alpha of 0.6147, the operationalization is sufficiently reliable; see Table 5.

--Insert Table 5 about here--

Observability *Observability* is also referred to as *result demonstrability* and corresponding operationalizations are proposed, for instance, by Moore and Benbasat [34] and Venkatesh and Davis [46]. Based on these operational definitions, we operationalize *observability* by the indicators 1) 'the ease to demonstrate results of an APS system', and 2) 'the ease to demonstrate advantages of an APS system'. Given a value of Cronbach's alpha of 0.8928, this operationalization is sufficiently reliable; see Table 6.

--Insert Table 6 about here--

Other users' opinions This construct is measured by a single indicator, as we ask the respondents how important they consider other users' opinions about the APS system.

Relative advantage Tornatzky and Klein [44] state that 'being better' is such a general notion that the measurement of *relative advantage* gives rise to several operationalization problems. For instance, Grover [19] needs 14 indicators to operationalize the construct *relative advantage*, among which 'improved performance', 'increased productivity', 'enhanced effectiveness', and 'general usefulness'[34,46,49]. We operationalize *relative advantage* by the indicators 1) 'the agility of creating a planning by an APS system', 2) 'the reduction in throughput time by implementing an APS system', 3) 'the increase in reliability by implementing an APS system', 4) the 'reduction in stock by implementing an APS system', 5) 'the increase in utilization rates by implementing an APS system', 6) 'the reduction in cost by implementing an APS system', and 7) 'the feasibility of plans created with an APS system'. Internal reliability of the scale is acceptable given the value of Cronbach's alpha of 0.7134; see Table 7.

--Insert Table 7 about here--

However, as *relative advantage* is a multi-indicator construct, we performed factor analysis on these seven indicators, for which the rotated factor solution is displayed in Table 8. Note that five indicators load on factor 1, and two indicators load on factor 2. Hence, the indicators of the scale of *relative advantage* measure two distinctive dimensions of *advantage*. As the five indicators loading on factor 1 indicate the logistics related advantage of an APS system, we indicate factor 1 as *logistics-related advantage* for factor 1. The last two indicators in Table 8 that load on factor two reflect the *package-related advantage* of working with an APS system.

--Insert Table 8 about here--

Total cost of ownership The cost of an innovation is generally operationalized by 'the initial purchasing costs of an innovation' [17,44]. However, expected implementation costs of most technical innovations are equally important prior to adoption. As a result, we operationalize total cost of ownership with the indicators 1) 'the cost of purchasing an APS system', and 2) 'the cost of implementation of an APS system'. With a value of Cronbach's alpha of 0.8951, the operationalization is sufficiently reliable; see Table 9.

--Insert Table 9 about here--

Trialability In concurrence with Zhao and Co [49], who operationalize *trialability* by 'the degree to which organizations obtained experience through a pilot project prior to implementation', we operationalize it by 'the possibility to experiment with an APS system before purchasing'.

Vendor support *Vendor support* has been studied by many researchers [17,49]. Based on their operationalization, we decided to operationalize *vendor support* by the indicators 1) 'the vendor support during implementation of an APS system', and 2) 'the offering of training programs by the vendor of an APS system', which is reliable given the value of Cronbach's alpha of 0.7488; see Table 10.

--Insert Table 10 about here--

5.2 Indicators for organizational constructs

ERP usage To discern ERP users from non-ERP users we only have to ask if the organization uses an ERP-system or not.

External communication Zmud [50] operationalizes *external communication* by 'payment of member dues to professional societies', 'providing members with subscription to professional literatures', 'sending members to technical workshops', and 'sending members to professional meetings'. Hence, it is about interpersonal communication channels and active information seeking employees [5,39]. However, occasionally researchers use the term *cosmopolitanism* for this construct [Kimberley and Evanisko (1981), 1] and the corresponding operationalizations are ‘conferences attended’, ‘summer institutes attended’, and ‘journals read regularly’. McGowan and Madey [32] also include industry publications, trading partners, EDI dedicated journals, and industry conferences. Since many of these indicators are concerned with information gathering by employees, we operationalize *external communication* by the following three indicators: 1) ‘frequency of employees’ visits to seminars on production and logistics’, 2) ‘employees’ reading of specialist literature on production and logistics’, and 3) ‘employees’ attendance on logistics courses’. With a value of Cronbach’s alpha of 0.7797, the internal reliability of this operationalization is sufficient, see Table 11.

--Insert Table 11 about here--

Functional differentiation Damanpour [9] uses the indicator ‘total number of units under the top management/chief executive level’, to operationalize *functional differentiation.* In addition, Kimberly and Evanisko [23] operationalize it by ‘the number of different subunits’. In concurrence with these operational definition, we also use the indicator ‘number of different departments’. Furthermore, we asked respondents whether the following functional departments were present: ‘a planning/logistics department’, an IT department’, and ‘an R&D department’. From these three dichotomous variables, we computed a new variable (with a 4-point scale) indicating ‘the richness of functional differentiation’. The value of this variable is 1 if the respondent indicates that none of these types of departments is present, the value is 2.33 if the respondent indicates that one of these types of departments is present, and the values is 3.67 or 5 for two respectively all three of these departments are present. As a result, we initially operationalize *functional differentiation* by 1) ‘the number of different departments’, and 2) ‘richness of functional differentiation’. Unfortunately, the value of Cronbach’s alpha is only 0.5631 and this is insufficient to indicate this scale as reliable; see Table 12. As a result, we only use the indicator ‘number of different departments within the organization’. Possible relations between the indicators ‘presence of a planning/logistics department’ and ‘the presence of an IT department’ and APS adoption are analyzed separately.

--Insert Table 12 about here--

Innovation experience Grover [19] uses the construct *technology policy* from which several indicators refer to our construct *innovation experience* (*e.g.* 'our organization has a long tradition of being the first to try new methods and technologies', and 'our organization spends more than others in the industry in developing new technology products'). However, we claim that degree of success of former innovations within an organization positively influences the willingness to adopt future innovations. Therefore, we use the indicators 1) 'in our firm we frequently implemented new applications/innovations', and 2) 'when we implement an innovation, this is generally successful' to operationalize *innovation experience*, which is reliable given the value of Cronbach's alpha of 0.7572; see Table 13.

--Insert Table 13 about here--

Internal communication Damanpour [9] operationalizes *internal communication* by 'the number of committees in an organization', 'the frequency of committee meetings', 'the number of contacts among people at the same and different levels', and 'the degree to which units share decisions'. Grover [19] operationalizes a related construct *integration* with the indicators 'joint development of projects occurs frequently with other departments', 'applications are often shared between departments', 'our organization encourages exchange of ideas between departments', 'data are often shared between departments', and 'projects are often initiated through joint interaction between departments'. All these indicators focus on the extent of interaction between departments. However, we consider the smoothness of the interdepartmental communication more important than the frequency of interdepartmental actions. Hence, we operationalize *internal communication* with the indicator 'within our firm the communication between departments is good'.

Management support *Management support* is frequently used in previous studies on innovation adoption and implementation [1,9,32,37,43]. Damanpour [9], for instance, operationalizes it as 'the managerial attitude toward change'. As a result, we operationalize *management support* by 'the managerial attitude toward innovation'

Size The construct *size* is generally measured by 'number of employees' [1,2,43,50]. We also operationalize *size* by the single indicator 'the total number of employees of the firm'.

Professionalism *Professionalism* is generally used as a determinant of adoption and implementation in innovation studies. Zhao and Co [49], for instance, measure *technical knowledge* by 'general knowledge of employees' and 'continued knowledge updating'. In addition, McGowan and Madey [32] ask for the existence of an 'expert'. Furthermore, Bigoness and Perrault [3] use the indicators: 'professionalism of line managers' and 'existence of an internal technical group'. Damanpour [9] operationalizes *professionalism* by 'the number or percentage of professional staff members with certain educational backgrounds', and 'the degree of professional training of organizational members'. Zmud [50] uses the indicators 'number of professionals possessing bachelor degrees', and 'number of professionals possessing master degrees'. Kimberly and Evanisko [23] and Brancheau and Wetherbe [5] ask for the level and substance of education of respondents. We operationalize *professionalism* by the indicators 1) 'the number of employees with a Bachelor degree in logistics', 2) 'the number of employees with a Master's degree in logistics', 3) 'frequency of hiring external logistics consultants'. With a value of Cronbach's alpha of 0.7074 this operationalization is internally reliable; see Table 14.

--Insert Table 14 about here--

5.3 Remaining indicators

As some operational definitions had to be rejected because of a low value of Cronbach's alpha, we have left some 'remaining' indicators for which we may analyze the possible relationship with APS adoption separately. These remaining indicators are 1) presence of an IT-department, 2) presence of a planning/logistics department, and 3) the number of end-products. In addition, there are two new multi-indicator constructs: *logistics-related advantage*, and *package-related advantage*. We assume that all these constructs are positively related to APS adoption.

6 Results: testing for associations

In this section, we briefly discuss the results of non-parametric statistical analysis to test for association between the ordinal and nominal constructs, as well as for possible spurious relations.

6.1 Correlation between the constructs and indicators

The constructs used in this study primarily have ordinal scales and occasionally nominal scales for which specific statistical procedures to falsify our hypotheses (*e.g.* the relationship and direction of the relationship between the constructs) are required. In addition, most of our hypotheses indicate a positive relationship between the independent construct and the dependent construct *APS adoption*. As a result, one-tailed (or one-sided) tests should be performed. However, a one-tailed test only checks whether the hypothesized direction is correct. If there is nonetheless a relationship, but oppositely directed, we receive no information on this relationship. In other words, despite the hypothesized directions between the constructs, we prefer the usage of two-tailed tests. Consequently, in this section we test for possible association with the help of two-tailed non-parametric statistical procedures.

APS adoption is a nominal-scaled variable. To test for association between this nominal-scaled variable and an ordinal-scaled variable, we use the Mann-Whitney U test and the Wilcoxon rank sum test. That is, we analyze the group of APS adopters versus the group of non-adopters with respect to these ordinal-scaled variables. The cases from both groups are combined and ranked, with the average rank assigned in the case of ties. Subsequently, the rank sum is calculated for both groups. From these rank sums, a test variable U (for the Mann-Whitney test), and a test variable W (for the Wilcoxon rank sum test) is calculated. Subsequently, the significance level (i.e. the *p*-value) is determined to investigate whether the null hypothesis 'there is no association' is to be rejected ($p<0.05$) or accepted ($p\geq0.05$). Although we tested all hypothesized relationships between all ordinal-scaled constructs with *APS adoption*, we only present significant results of these Mann-Whitney and Wilcoxon rank sum tests; see Table 15.

--Insert Table 15 about here--

From Table 15, we note that the constructs *management support*, *other users' opinions*, *number of end-products*, and *innovation experience* are significantly related to *APS adoption*. Although we hypothesized a directed relationship between an independent construct and *APS adoption*, the Mann-Whitney and Wilcoxon rank sum tests do not clarify this direction. Therefore, we investigate the cross tabulation of *APS adoption* with these constructs; see Table 16. From this crosstabulation, we note that, except for *other users'* opinions, the mean for all constructs for APS adopters is higher than the mean for non-adopters, which indicates a positive relationship between the constructs and *APS adoption.* From the differences in mean for APS adopters and non-adopters, we note that the construct *other users' opinions* is negatively related to *APS adoption*. This indicates that organizations that value *other users' opinions* about APS systems significantly adopt APS less often than organizations that consider these opinions not important.

--Insert Table 16 about here--

To test the relationship between two nominal-scaled constructs, we use a φ-test (which is an option of the chi-square test within crosstabs in the software package SPSS, where φ is defined as a chi-square based measure of relationship). If the significance value of φ is smaller than 0.05, there is a relationship between the two nominal constructs.

There are several options for calculating the significance value of φ. We decided to use the exact method, as exact tests can obtain reliable significance levels without preliminary data requirements in contrast with the asymptotic method, in which it is required that cell frequencies in the contingency tables are not smaller than five. Unfortunately, the only nominal-scaled construct that appears to be significantly related to *APS adoption* is *planning/logistics department*; see Table 17.

--Insert Table 17 about here--

The nature of the relationship between *APS adoption* and *planning/logistics department* is clarified by the contingency matrix displayed in Table 18, from which we note that *planning/logistics department* is positively related to *APS adoption*, since 19.6% of all respondents with a *planning/logistics department* had adopted an APS system, in contrast with only 2.8% of the respondents that do not have a *planning/logistics department*. Furthermore, we note that one of the cell frequencies of Table 18 is smaller than five for which the asymptotic method of calculating the significance value would have given us an unreliable result.

--Insert Table 18 about here--

The results from the analyses discussed in this section are displayed in a conceptual/statistical model for *APS adoption*; see Fig. 2 (a).

6.2 Spurious relationships

In the previous section, we found some significant relationships between the innovation and organizational constructs and *APS adoption*. Nevertheless, we have to be cautious for possible spurious relationships. A spurious relationship refers to a situation in which measures of two or more variables are statistically related (i.e. they cover) but are not in fact causally linked, usually because the statistical relationship is caused by a third variable. Therefore, we have to test all significant relationships on spuriosity to obviate the effects of such third variable.

From the previous section, we found the ordinal-scaled constructs *innovation experience, management support*, *number of end-products*, and *other users' opinions* to be associated with *APS adoption*. If one of these relationships is spurious, there must be a 'lurking' variable. However, we generally have no prior knowledge on which variables are 'lurking'. We, therefore, view all constructs potentially lurking. In case the lurking construct is ordinal-scaled, we divide the sample in two groups (*e.g.* a group of respondents with a 'low score' on the lurking construct and a group of respondents with a 'high score' on the lurking construct). Subsequently, we perform a Mann-Whitney U test for both groups, to test the relationship between the dependent construct and the independent construct. When this relationship is still significant for both groups, the relationship is 'autonomous', but when the relationship is not significant for one or both groups, the relationship might be spurious. However, the significance of the Mann-Whitney test can also decrease because of smaller sample size. Thus, we do not only test the significance of the correlation, as measured with the Mann-Whitney U test, but we also test the extent of correlation. Since the dependent construct *APS adoption* is a nominal-scaled (i.e. dichotomous) construct, we test the correlation between a nominal-scaled (dependent) and an ordinal-scaled (independent) construct. However, to the best of our knowledge there is no numerical measure for this type of correlation. To measure correlation between two ordinal-scaled variables a Spearman's ρ test is generally used; to measure correlation between two nominal-scaled variables a φ-test is generally used. We decided to use both tests to measure the extent of correlation for the different groups. When there is a *decrease* of at least 5% for both correlation measures, we indicate the construct to be lurking and the initial relationship between the independent and dependent construct is spurious. For possible nominal-scaled lurking constructs, we perform a similar procedure with the Mann-Whitney U test for all options in the corresponding scale.

-- Insert Fig. 2 about here --

The results of these tests are displayed in Fig. 2 (b). *Innovation experience, size* and *total cost of ownership* appeared to be possible lurking constructs in the spurious relationship between *APS adoption* and *management support*. *Observability*, and *package-related advantage* appeared to be possible lurking constructs in the spurious relationship between *APS adoption* and *other users' opinions*. *Size* appeared to be a possible lurking construct in the spurious relationship between *APS adoption* and *number of end-products*. *Management support* and *professionalism* appeared to be possible lurking constructs in the spurious relationship between *APS adoption* and *innovation experience*. As a result, we obtained two theory-based models for *APS adoption*: one model without spurious relationships, and one model with spurious relationships; see Fig. 2 (a) and (b).

7 Results: testing for causal relationships

With the help of non-parametric statistical analysis, we obtained two conceptual models with significant associations between the independent constructs and the dependent variable *APS adoption*. Furthermore, we identified possible spurious relationships between these constructs and a number of 'lurking' variables. To analyze the causal effects as displayed in these conceptual models and the presence of spurious relationships, we develop and analyze structural models of both conceptual models where we assume that the ordinal variables are representations of underlying continuous variables [47]. There is, however, no point in proceeding to any structural model until *the researcher* is satisfied the measurement model is valid. As a result, Kline [24] urges structural equations modeling (SEM) researchers to always test the pure measurement model underlying a full structural equation model first, and if the fit of the measurement model is found acceptable, then to proceed to the second step of testing the structural model by comparing its fit with that of different structural models (*e.g* with models generated by trimming or building, or with mathematically equivalent models). In this study, we follow Kline's [24] recommendation. That is, we developed and validated the measurement models (i.e. confirmatory factor analysis) first, which are evaluated like any other SEM model, using the goodness of fit measures x^2/d.f. ratio, CFI, NFI, TLI, and RMSEA. By convention, NFI values below .90 indicate a need to respecify the model. Consequently, we require NFI > .90. Furthermore, we require TLI (NNFI) > .95 and indicate models with RMSEA ≤ .065 to have good fit and .1 > RMSEA > .065 for adequate fit [6,22,24].

In section 7.1, we discuss the measurement model and the structural model that corresponds with the conceptual model of *APS adoption* without spurious relationships, and in section 7.2, we discuss the structural model that corresponds with the conceptual model of *APS adoption* with spurious relationships

7.1 Initial model without spurious relationships

7.1.1 Initial measurement model

In this section, we discuss the confirmatory factor analysis of the conceptual model of *APS adoption* without spurious relationships, i.e. model (a) in Fig. 2. The corresponding measurement model as displayed in Fig. 3 fits the data according the fit indices x^2 = 10.819, d.f. = 7, p_{model} = 0.147, CFI = 0.998, TLI = 0.993, NFI = 0.993, and $RMSEA_{[0,0.137]}$ = 0.065.

Fig. 3 displays squared multiple correlations (R^2) for each indicator, indicating the level of explained variance. Fortunately, the R^2-values are quite high. For example, this model explains 77% of the variance of the indicator ‘organization frequently implements innovations’.

--Insert Fig. 3 about here--

The unstandardized factor loadings are interpreted as regression coefficients that indicate expected change in the indicator given a 1-point increase in the factor. For example, scores on the ‘implementations of innovations are generally successful’ are predicted to increase by 0.65 points for every 1-point increase in the *innovation experience* factor. Standardized loadings (in parenthesis) are interpreted as correlations and their squared values as proportions of explained variance. The standardized factor loading of the ‘implementations of innovations are generally successful’, for instance, is 0.70, which means that 0.70^2, or 49% of its variance is shared with the *innovation experience* factor. Given the reasonable high factors loadings convergent validity is acceptable. We, therefore, continue this section with the analysis of an initial structural model of *APS adoption*, based on this simple measurement model.

7.1.2 Structural model

In this section, we discuss the structural model of the conceptual model of *APS adoption* without spurious relationships, i.e. model (a) in Fig. 2. The structural model that is obtained after the removal of non-significant paths essentially reduces to a simple regression model as displayed in Fig. 4. This final structural model fits the data according to the fit indices x^2 = 2.398, d.f. = 3, p_{model} = 0.494, CFI = 1.000, NFI = 0.997, TLI= 1.000, and $RMSEA_{[0,0.137]}$ = 0.

--Insert Fig. 4 about here--

In Fig. 4, the unstandardized beta coefficients and disturbances terms are represented as normal numbers; standardized beta coefficients are represented in parentheses. The disturbance term for the endogenous construct *APS adoption*, indicates the unexplained variance in the endogenous variable due to all unmeasured causes, and the squared multiple correlation (R^2) indicates the level of explained variance by the model. Note that this model explains 17% of the variance of *APS adoption*.

7.2 Testing for spurious relationships

7.2.1 Measurement model of APS adoption with spurious relationships

In this section, we briefly discuss the measurement model of the extended conceptual model of *APS adoption* with spurious relationships, i.e. model (b) in Fig. 2. After elimination of non-significant factor loadings and covariances, we obtained the measurement model as displayed in Fig. 5. This measurement model fits the data according to the relative fit indices x^2 = 240.891, d.f. = 143, p_{model} = 0.000, CFI = 0.985, TLI = 0.969, NFI = 0.965, and $RMSEA_{[0.057,0.089]}$ = 0.073. The corresponding covariances between the factors are displayed in Table 19. In addition, given the sufficient large factor loadings and low measurement errors of the indicators, convergent validity of this model is acceptable. Hence, we continue the analysis of a structural model based on this measurement model.

--Insert Fig. 5 about here--

Note, however, that we analyzed the indicators of both *total cost of ownership* and *package-related advantage* independently as the factor loadings of the indicators were non-significant.

--Insert Table 19 about here--

7.2.2 Structural model of APS adoption with spurious relationships

In this section, we discuss the structural model of the conceptual model of *APS adoption* with spurious relationships, i.e. model (b) in Fig. 2. From the corresponding measurement model, we note that *size* is only related to *professionalism* and, therefore, only indirectly related to *APS adoption*. Based on the covariances displayed in Table 19 and the directions of the paths in conceptual model (b) of Fig. 2, we developed and analyzed structural models of *APS adoption* with spurious relationships. After the removal non-significant paths, we obtained the final structural model as displayed in Fig. 6. This model fits the data according the fit indices x^2 = 192.781, d.f. = 116, p_{model} = 0.000, CFI = 0.984, NFI = 0.960, TLI= 0.978, and $\text{RMSEA}_{[0.053,0.092]}$ = 0.072.

Note, that this model displays direct relationships between the constructs *management support, cost of purchase*, *number of end-products*, *other users' opinions,* and *APS adoption* and indirect relationships between *professionalism, external communication*, *innovation experience*, and *observability* and *APS adoption*. In addition, note that this model explains 21% of the variance of *APS adoption*.

From this final structural model, we note that the more different end-products an organization manufactures, the more likely it will adopt an APS system. Contrarily, the higher the value of *cost of purchasing* an APS system, the lower the APS adoption rate. Furthermore, organizations that value *other users' opinions* about APS systems significantly adopt APS less often than organizations that consider these opinions not important. This is strengthened by the levels of *observability*. Organizations that value the *observability* of APS systems (i.e. organizations that attach importance to the ease of demonstrating results and advantages of the APS system above the present way of working) also significantly adopt APS less often than organizations that consider *observability* as less important.

--Insert Fig. 6 about here--

In concurrence with the general findings on innovation research, the structural model shows that *management support* for adopting innovations increases with higher levels of *innovation experience* [5,9,50]. The organizational level of *innovation experience* is partly determined by *external communication* and (indirectly) *professionalism.* These variables axplain 29% of the variance of the variable *innovation experience.* This means that organizations with higher levels of education and active information-seeking attitudes generally have higher levels innovation experience, which is in concurrence with the results of previous studies on adoption of innovations. Zmud [50] found that subscriptions, a library, and consultant training are positively associated with innovativeness. Brancheau and Wetherbe [5] conclude that earlier adopters predominantly more frequently engage in external communication than late adopters. Furthermore, note that this model explains 29% of the variance of *innovation experience*, which is quite high since we primarily investigated the impact of innovation and organizational factors on the adoption of APS systems.

Furthermore, note that, given our definition of APS, there is no direct relation between *APS adoption* and *size*. Nevertheless, *size* influences the level of professionalism and, hence, indirectly the adoption of APS systems.

8 Discussion, conclusions, and further research

8.1 Discussion

In this paper, we have demonstrated that *management support, cost of purchase*, *number of end-products*, and *other users' opinions* are factors that directly influences the adoption of APS systems. A supportive management attitude toward the innovation creates an internal climate conducive to innovation [9] and indirectly leads to higher rates of adoptions of innovations. As *professionalism*, *external communications*, and *innovation experience* influence the level of *management support* (R^2 = .20), these variables indirectly influence APS adoption; see Table 20.

--Insert Table 20 about here--

Put differently, the more active information-seeking attitude the organization has, the higher the level of *innovation experience,* and the higher the *management support*, and the higher the adoption rate of APS systems. This concurs with the findings of the study of Damanpour [9]. In addition, Thong and Yap [43] state that businesses with CEOs who have more positive attitude towards adoption of IT are more likely to adopt IT directly.

Cost of purchase has a negative effect on *APS adoption*. This concurs with the conclusions of Gerwin [17] and Tornatzky and Klein [44] that cost is negatively related to the adoption and implementation of innovations. However, Cooper and Zmud [8] assume that a large investment will highly motivate diffusion indicating that cost is positively related to the extent of implementation.

Another negative effect on *APS adoption* is the importance the organizations attach to *other users' opinions*. The more an organization values other users' opinions, the less likely the organization adopts an APS system. In addition, *observability* has an indirect effect on *APS adoption* via *other users' opinions*. Thus, organizations that attach importance to the ease to demonstrate the results and advantages of an APS system also value *other users' opinions* about the APS system. ANOVA analysis indicates that organizations with high scores on *innovation experience* have significant lower means for *other users' opinions* and *observability* compared to organizations with low scores on *innovation experience*. This indicates that organizations with less *innovation experience* perceive more uncertainty about a new technology such as an APS system, have more negative attitudes towards the innovation, and attach greater importance to other users' opinions and the *observability* of the APS system.

Professionalism indirectly influences *APS adoption,* which concurs with findings of Zhao and Co [49] that general technical knowledge of employees is significantly associated with successful adoption of advanced manufacturing technology. Moreover, these findings are also supported by Dewar and Dutton [12], who found that extensive knowledge is important for the adoption of technical process innovations.

8.2 Managerial implications

If management wants to adopt an APS system successfully it must create an internal climate conducive to the innovation by supporting to increase external communication levels such as in-house training programs to enhance the *professionalism* within the organization. This is especially true if the level of innovation experience is rather low [17,19]. In addition, successful implementations of ERP systems require strong leadership, commitment, and participation by top management [29]. Based on the structural models, we postulate that this also holds for APS systems. Unfortunately, many chief executives make the mistake to view ERP as simply a software system and the implementation of the ERP system as a technological challenge [45]. APS implementation projects range from specific improvements on a functional level to large-scale change programs, involving the redefinition of the business strategy and redesign of the business [42] –which is quite similar as with ERP systems– where the role of executive management is to enable the change of procedures across multiple functional areas [13].

8.3 Limitations and directions for future research

From the results of the structural model, it appeared that *logistics-related advantage*, *compatibility* and *adaptation* are not significantly related to APS adoption. For the constructs *compatibility* and *adaptation*, this is probably due to the used operational definitions as it is commonly accepted that most technological innovations require mutual adaptation of the new technology to the organization and the organization to the technology [17,30], and for advanced software technology in particular [4,42].

However, relative advantage was initially operationalized into two dimensions: *logistics-related advantage* and *package-related advantage.* The latter construct appeared to be a potential lurking construct in the relation between *other users' opinion*s and *APS adoption*, as displayed in Fig. 2 (b), but this was not confirmed in the structural models. However, these types of advantages may impact the successful implementation of APS as these issues are important for successful implementation of ERP systems [21,41]. Future research could clarify these issues.

There are various other directions for further research, amongst which the investigation of the impact of other factors on APS adoption, for instance complexity factors because of the Product/Market/Technology characteristics of manufacturing environments in relation with the general APS capabilities. Recall that the *number of end-products* directly influences the adoption of APS. Since the unexplained variance of the variable APS adoption due to all not-included factors in the structural model displayed in Fig. 6 is 79%, analysis of other complexity and uncertainty factors that might influence APS adoption seems justified.

Furthermore, this study only concerns APS adoption, not implementation. Future research could focus on other stages of the stage model of IT implementation, such as acceptance, routinization and infusion [26,8]. Furthermore, it is required to study APS justification [48] by investigating the operational and financial benefits of using an APS system.

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Internet links

[i] (http://www.burns.com/wcbspurcorl.htm).

[ii] (http://www.eim.net/AOnd_spd_int/Start.asp?).

10 Appendix: Questionnaire

No.	Question	Scale	Answers
General information			
1	The sector our firm operates in is:	Nominal	Metal / machine / chemical / textile- and leather products / electronic apparatus / transport devices / wood / construction materials and glass / furniture / paper and paper products / other.
2	The entire turnover of our firm is:	Ordinal	Less than €500,000 / €500,000 - €1,000,000 / €1,000,001 - €5,000,000 / €5,000,001 - €15,000,000 / More than €15,000,000.
3	The number of different departments within our firm is:	Ordinal	1 / 2 or 3 / 4 – 6 / 7 – 10 / more than 10.
4	The total number of employees of or firm is:	Ordinal	Less than 20 / 20 – 49 / 50 – 99 / 100 – 199 / 200 – 499 / 500 or more.
5	The number of employees with a Bachelor degree in logistics in our firm is:	Ordinal	0 / 1 / 2 or 3 / 4 – 8 / more than 8.
6	The number of employees with a Master's degree in logistics in our firm is:	Ordinal	0 / 1 / 2 or 3 / 4 – 8 / more than 8.
7	The number of managers in our firm is:	Ordinal	1 or 2 / 3 or 4 / 5 – 8 / 9 – 12 / more than 12.
8	In our firm there is one Planning / Logistics department that determines the planning.	Nominal	Yes / no.
9	In our firm there is one IT department that executes all IT-tasks.	Nominal	Yes / no.
10	In our firm there is a R&D department.	Nominal	Yes / no.
Market			
11	The number of customers of our firm is:	Ordinal	1 – 10 / 11 – 20 / 21 – 50 / 51 – 100 / more than 100.
12	The average number of orders our firm processes in a month is:	Ordinal	1 – 5 / 6 – 10 / 11 – 50 / 51 – 100 / more than 100.
13	The distribution of the orders is:	Ordinal	Only one-off orders / mostly one-off orders / as much one-off as repetitive orders / mostly repetitive orders / only repetitive orders / unknown.
14	The number of suppliers of our firm is:	Ordinal	1 – 5 / 6 – 10 / 11 – 25 / 26 – 50 / more than 50 / unknown.
15	The number of competitors for our firm in the Netherlands is:	Ordinal	0 / 1 – 5 / 6 – 10 / 11 – 20 / more than 20 / unknown.
16	The competitive position of our firm in the Netherlands is:	Ordinal	Market leader / top 5 / top 10 / top 20 / lower than top 20 / unknown.
17	The market in which our firm operates can be characterized as:	Nominal	Shrinking market / stable market / expanding market / fluctuating market / unknown.
Production process			
18	The number of production locations of our firm is:	Ordinal	1 / 2 / 3 / 4 / more than 4.
19	The layout of the production location(s) is based on:	Nominal	Process layout (job-shop) / product layout (flow-shop) / fixed position layout (product stays in place) / group technology layout (mix of process and product layout).
20	The number of different end products our firm produces is:	Ordinal	1 – 10 / 11 – 20 / 21 – 50 / 51 – 100 / more than 100.
21	What is the degree of customer specific production?	Ordinal	Totally customer specific / there are customer specific variations / standard products with standard variations / only standard products.
22	The production strategy our firm uses for the most important products is:	Ordinal	Engineer to order / make to order / assemble to order / make to stock / other.
Planning			
23	The amount of weeks for which the production planning is made (planning horizon) is:	Ordinal	0 - 1 Week / 2 - 4 weeks / 5 - 8 weeks / 9 - 16 weeks / more than 16 weeks / unknown.
24	The frequency of making a production planning is:	Ordinal	Daily / weekly / once in two weeks / once a month / less than once a month.
25	At our firm we use an Enterprise Resources Planning (ERP) system.	Nominal	Yes / no.
26	The supplier of our ERP system is:	Nominal	
27	In our firm we use an APS system or we are implementing an APS system.	Nominal	Yes / no.
28	The supplier of our APS system is:	Nominal	
29	The number of departments in our firm that uses the APS system is:	Ordinal	1 / 2 / 3 / 4 / more than 4.
30	The number of people in our firm that use the APS system is:	Ordinal	1 / 2 or 3 / 4 – 6 / 7 – 10 / more than 10.
31	At our firm we use all technological possibilities of the APS system.	Ordinal	Totally agree / agree / neither agree nor disagree / disagree / totally disagree.
32	Which modules of the APS system are used within your firm (multiple answers allowed)?	Nominal	Strategic Network Planning / Master Planning / Demand Planning / Demand Fulfilment & Available To Promise / Distribution Planning / Transport Planning / Production Planning / Scheduling / Material Requirements Planning.
33	Which modules of the APS system have been the most advantageous for your firm (multiple answers allowed)?	Nominal	Strategic Network Planning / Master Planning / Demand Planning / Demand Fulfilment & Available To Promise / Distribution Planning / Transport Planning / Production Planning / Scheduling / Material Requirements Planning.
34	At our firm we have the intention to adopt an APS system in the near future.	Nominal	Yes / no
35	The available budget for purchasing an APS system is:	Ordinal	€ 0 / €1 - €25,000 / €25,001 - €50,000 / €50,001 - €100,000 / more than €100,000.
36	Which APS modules will you use in your firm (multiple answers allowed)?	Nominal	Strategic Network Planning / Master Planning / Demand Planning / Demand Fulfilment & Available To Promise / Distribution Planning / Transport Planning / Production Planning / Scheduling / Material Requirements Planning.

No.	Question	Scale	Answers
Arguments for adoption decision			
37	Cost of purchasing an APS system.	Ordinal	Very unimportant / unimportant / neither unimportant nor important / important / very important / unknown / not applicable.
38	Cost of implementation of an APS system.	Ordinal	Very unimportant / unimportant / neither unimportant nor important / important / very important / unknown / not applicable.
39	The possibility to experiment with an APS system before purchasing.	Ordinal	Very unimportant / unimportant / neither unimportant nor important / important / very important / unknown / not applicable.
40	The possibility for step-wise implementation of an APS system.	Ordinal	Very unimportant / unimportant / neither unimportant nor important / important / very important / unknown / not applicable.
41	The ease to understand an APS system.	Ordinal	Very unimportant / unimportant / neither unimportant nor important / important / very important / unknown / not applicable.
42	The ease to use an APS system.	Ordinal	Very unimportant / unimportant / neither unimportant nor important / important / very important / unknown / not applicable.
43	The degree of compatibility of an APS system with the existing firm's culture.	Ordinal	Very unimportant / unimportant / neither unimportant nor important / important / very important / unknown / not applicable.
44	The degree of compatibility of an APS system with the current way of planning.	Ordinal	Very unimportant / unimportant / neither unimportant nor important / important / very important / unknown / not applicable.
45	The degree to which an APS system can be integrated with an existing ERP system.	Ordinal	Very unimportant / unimportant / neither unimportant nor important / important / very important / unknown / not applicable.
46	The agility of creating a planning by an APS system.	Ordinal	Very unimportant / unimportant / neither unimportant nor important / important / very important / unknown / not applicable.
47	Reduction in throughput time by implementing an APS system.	Ordinal	Very unimportant / unimportant / neither unimportant nor important / important / very important / unknown / not applicable.
48	Increase in reliability by implementing an APS system.	Ordinal	Very unimportant / unimportant / neither unimportant nor important / important / very important / unknown / not applicable.
49	Reduction in stock by implementing an APS system.	Ordinal	Very unimportant / unimportant / neither unimportant nor important / important / very important / unknown / not applicable.
50	Increase in utilization rates by implementing an APS system.	Ordinal	Very unimportant / unimportant / neither unimportant nor important / important / very important / unknown / not applicable.
51	Reduction in cost by implementing an APS system.	Ordinal	Very unimportant / unimportant / neither unimportant nor important / important / very important / unknown / not applicable.
52	The feasibility of plans created with an APS system.	Ordinal	Very unimportant / unimportant / neither unimportant nor important / important / very important / unknown / not applicable.
53	The ease to demonstrate advantages of an APS system.	Ordinal	Very unimportant / unimportant / neither unimportant nor important / important / very important / unknown / not applicable.
54	The ease to demonstrate results of an APS system.	Ordinal	Very unimportant / unimportant / neither unimportant nor important / important / very important / unknown / not applicable.
55	The ease to change an APS system to altered circumstances.	Ordinal	Very unimportant / unimportant / neither unimportant nor important / important / very important / unknown / not applicable.
56	The possibility to run what-if analysis with an APS system.	Ordinal	Very unimportant / unimportant / neither unimportant nor important / important / very important / unknown / not applicable.
57	The possibility to adapt the results generated by an APS system by hand.	Ordinal	Very unimportant / unimportant / neither unimportant nor important / important / very important / unknown / not applicable.
58	Other users' opinions about an APS system.	Ordinal	Very unimportant / unimportant / neither unimportant nor important / important / very important / unknown / not applicable.
59	Vendor support during implementation of an APS system.	Ordinal	Very unimportant / unimportant / neither unimportant nor important / important / very important / unknown / not applicable.
60	The offering of training programs by the vendor of an APS system.	Ordinal	Very unimportant / unimportant / neither unimportant nor important / important / very important / unknown / not applicable.
61	Familiarity with the vendor of an APS system.	Ordinal	Very unimportant / unimportant / neither unimportant nor important / important / very important / unknown / not applicable.
Agreement with propositions			
62	The management of our firm generally has a positive attitude towards innovation.	Ordinal	Totally disagree / disagree / neither disagree nor agree / agree / totally agree / unknown / not applicable.
63	Employees of our firm frequently visit seminars on production and logistics.	Ordinal	Totally disagree / disagree / neither disagree nor agree / agree / totally agree / unknown / not applicable.
64	Employees of our firm frequently read specialist literature on production and logistics.	Ordinal	Totally disagree / disagree / neither disagree nor agree / agree / totally agree / unknown / not applicable.
65	Employees of our firm frequently attend logistics courses.	Ordinal	Totally disagree / disagree / neither disagree nor agree / agree / totally agree / unknown / not applicable.
66	At our firm everybody can bring up ideas and innovations.	Ordinal	Totally disagree / disagree / neither disagree nor agree / agree / totally agree / unknown / not applicable.
67	Within our firm the communication between departments is good.	Ordinal	Totally disagree / disagree / neither disagree nor agree / agree / totally agree / unknown / not applicable.
68	Within our firm we are familiar with advanced planning techniques.	Ordinal	Totally disagree / disagree / neither disagree nor agree / agree / totally agree / unknown / not applicable.
69	Within our firm we are familiar with the working, advantages and disadvantages of APS systems.	Ordinal	Totally disagree / disagree / neither disagree nor agree / agree / totally agree / unknown / not applicable.
70	Within our firm there is a specialist on APS systems.	Ordinal	Totally disagree / disagree / neither disagree nor agree / agree / totally agree / unknown / not applicable.
71	In our firm we frequently implemented new applications/innovations.	Ordinal	Totally disagree / disagree / neither disagree nor agree / agree / totally agree / unknown / not applicable.
72	When we implement new applications this generally is successful.	Ordinal	Totally disagree / disagree / neither disagree nor agree / agree / totally agree / unknown / not applicable.
73	The setup and operation times of the production process are known precisely.	Ordinal	Totally disagree / disagree / neither disagree nor agree / agree / totally agree / unknown / not applicable.
74	The planning created with our current system has to be adapted frequently.	Ordinal	Totally disagree / disagree / neither disagree nor agree / agree / totally agree / unknown / not applicable.
75	The demand of our customers is predictable to a great extent.	Ordinal	Totally disagree / disagree / neither disagree nor agree / agree / totally agree / unknown / not applicable.
76	The rate of change in demand is high.	Ordinal	Totally disagree / disagree / neither disagree nor agree / agree / totally agree / unknown / not applicable.
77	Our firm frequently hires external logistics consultants.	Ordinal	Totally disagree / disagree / neither disagree nor agree / agree / totally agree / unknown / not applicable.

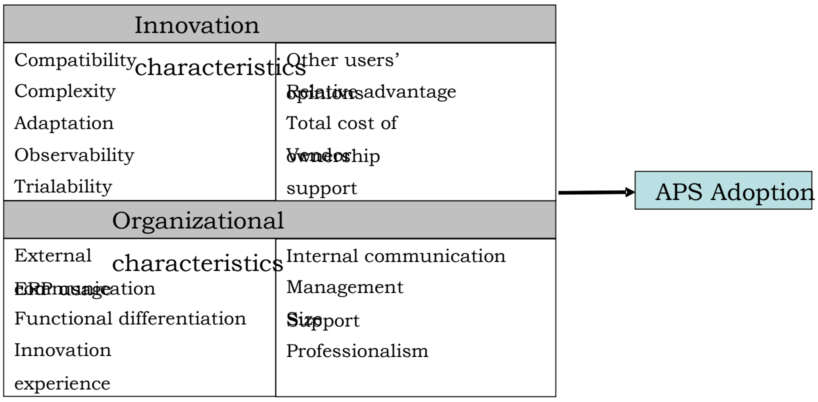

Fig. 1: APS adoption meta-model.

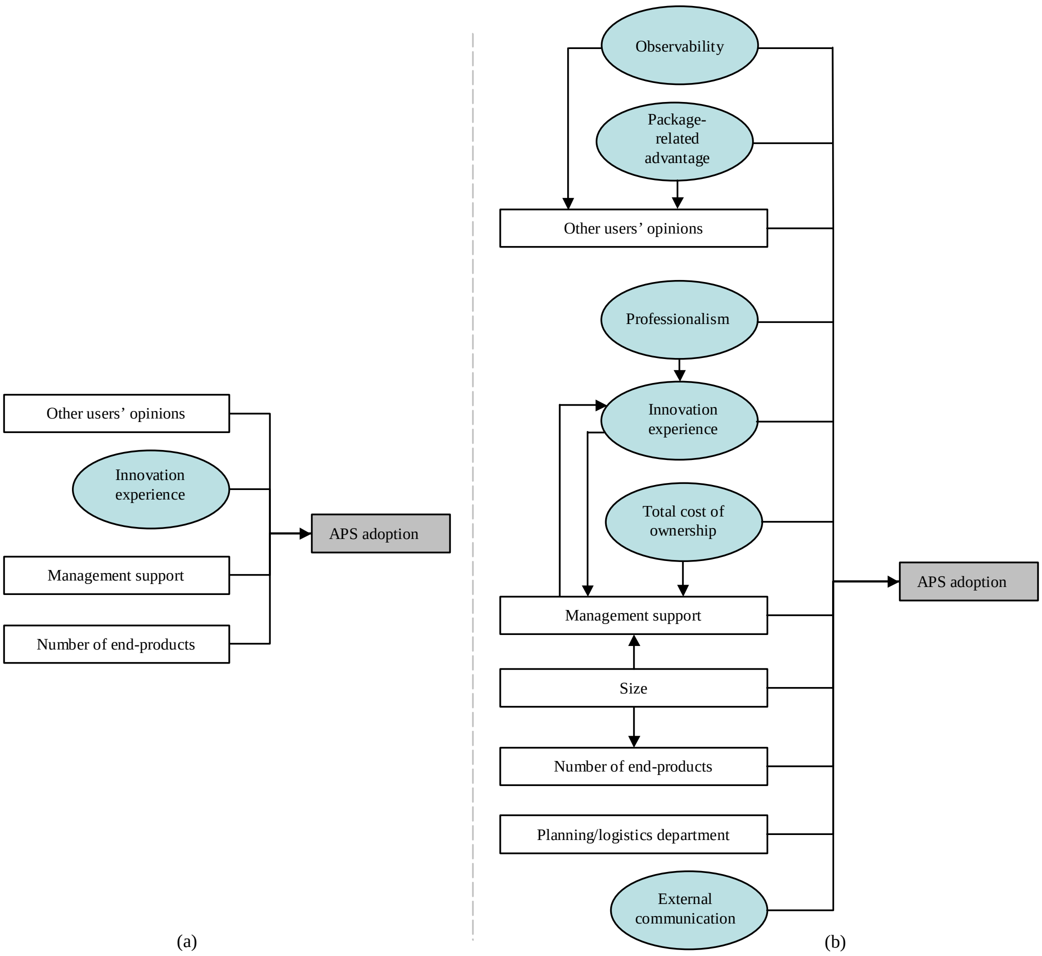

Fig. 2: APS adoption model without spurious relationships (a) and with (b) spurious relationships.

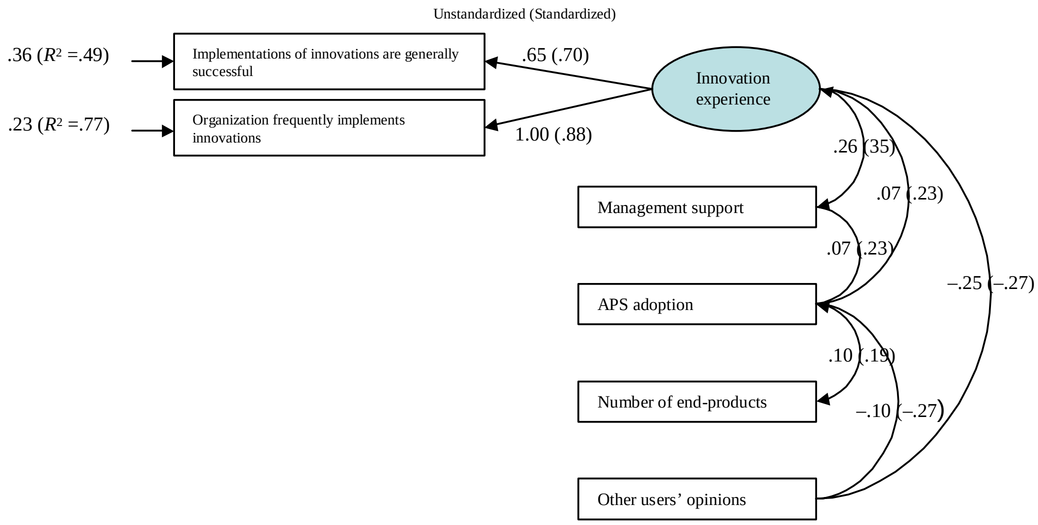

Fig. 3: Initial measurement model of APS adoption.

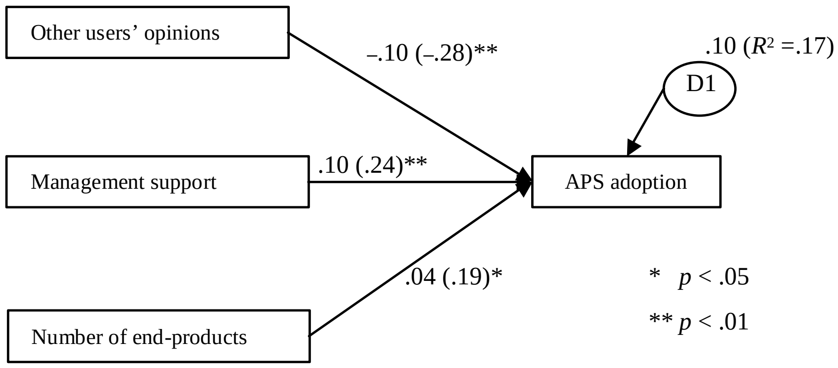

Fig. 4: Final basic structural model of APS adoption.

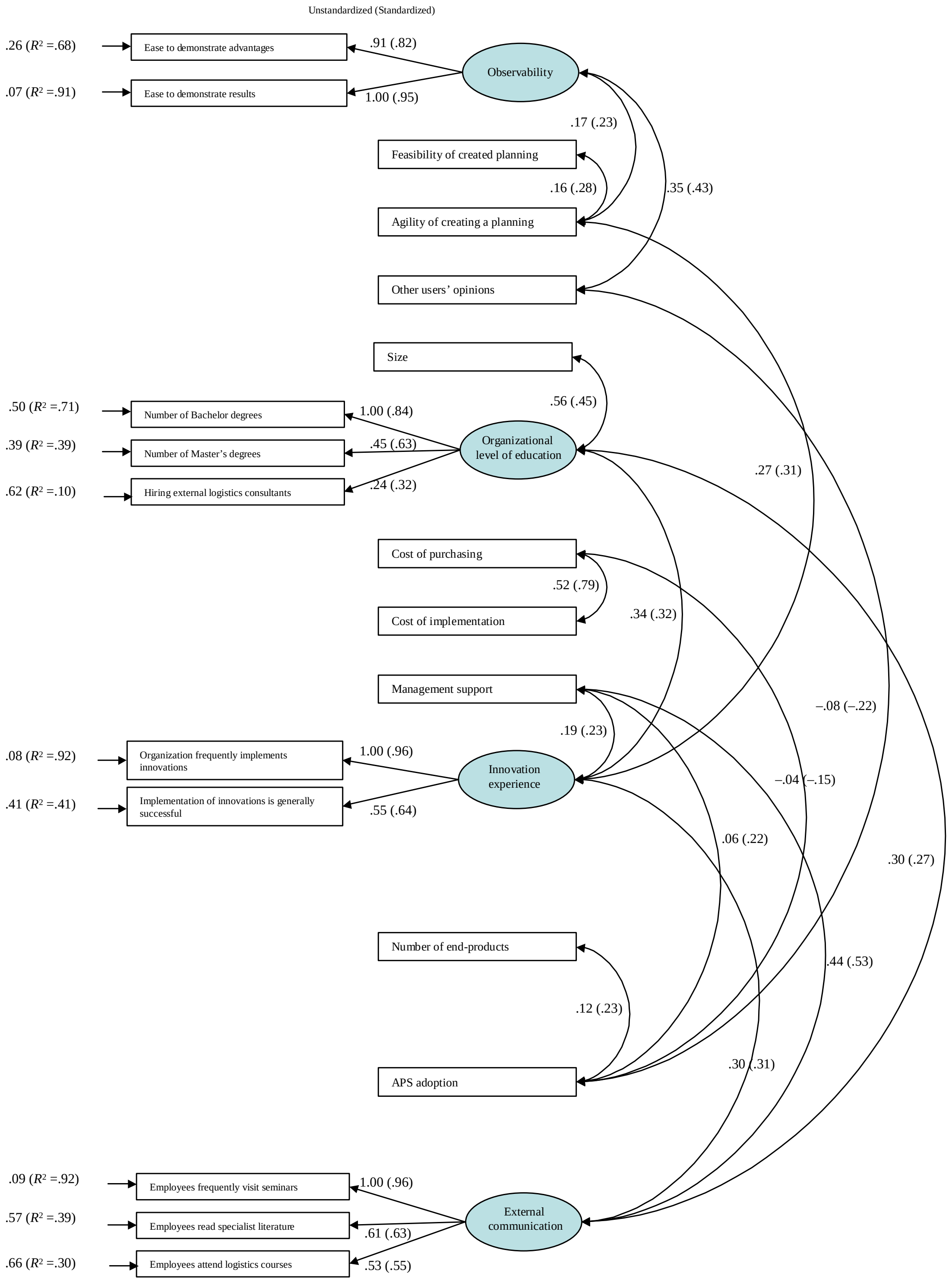

Fig. 5: Measurement model of APS adoption with spurious relationships.

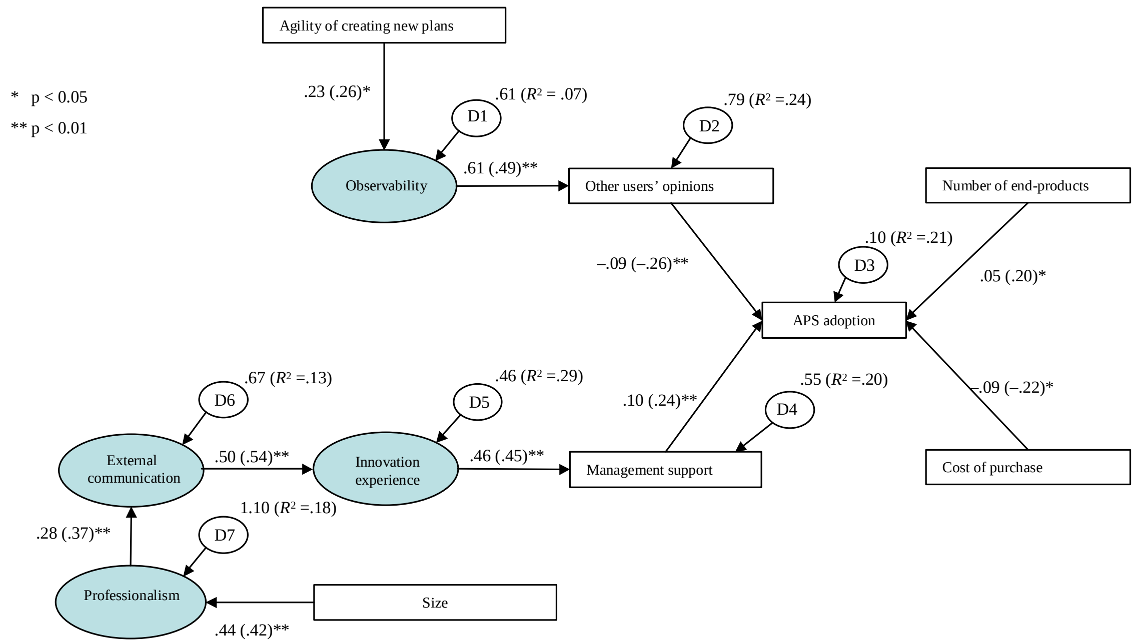

Fig. 6: Final structural model of APS adoption.

ISIC code	Industry description	No. (%) of responses
27, 28	Basic metals and fabricated metal	81 (59.4)
29, 30,	Machinery and equipment	20 (14.5)
17, 19	Textiles and leather	1 (0.6)
31, 32, 33	Electrical machinery and apparatus	7 (4.8)
34, 35	Transport equipment	1 (0.6)
20	Wood and products of wood and cork	3 (2.4)
36	Construction materials and glass	3 (2.4)
21	Paper and paper products	2 (1.8)
36	Furniture	4 (2.9)
	Other	14 (10.3)
Total		**136 (100.0)**

Table 1: Distribution of sectors in the sample.

Type of respondents	No. (%) of responses
Manager OM	62 (45.6)
Manager IT	12 (8.8)
Manager General	24 (17.6)
Operational OM (Planners and Specialists)	18 (13.2)
Operational IT	2 (1.5)
Unknown	18 (13.2)
Total	136 (100.0)

Table 2: Function of respondents.

Indicators	Pearson correlation		Mean	S.D.	Cronbach's alpha
Compatibility with firm's culture	1.0000		4.1078	0.9740	0.6451
Compatibility with current way of planning	0.4763***	1.0000	3.6373	1.0029	

**** Significant at p<0.01;** Significant at p<0.05*

Table 3: Operational definition of *compatibility*.

Indicators	Pearson correlation		Mean	S.D.	Cronbach's alpha
Ease to understand an APS system	1.0000		4.3981	0.6618	0.7795
Ease to use an APS system	0.6485***	1.0000	4.5534	0.5553	

**** Significant at p<0.01*

Table 4: Operational definition of *complexity*.

Indicators	Pearson correlation			Mean	S.D.	Cronbach's alpha	alpha if indicator deleted
Ease to adapt to changing circumstances	1.0000			4.3333	0.6389	0.6147	0.5857
Possibility to run what-if analysis	0.2279**	1.0000		3.9596	0.7944		0.5660
Possibility to adapt results by hand	0.4015***	0.4144***	1.0000	4.2020	0.7690		0.3641

**** Significant at p<0.01; ** Significant at p<0.05*

Table 5: Operational definition of *adaptation* .

Indicators	Pearson correlation		Mean	S.D.	Cronbach's alpha
Ease to demonstrate advantages	1.0000		3.4951	0.9169	0.8928
Ease to demonstrate results	0.8068***	1.0000	3.6893	0.8859	

**** Significant at p<0.01*

Table 6: Operational definition of *observability*.

Indicators	Pearson correlation							Mean	S.D.	Cronbach's alpha	alpha if indicator deleted
Agility of creating a planning	1.0000							3.8854	0.9389	0.7134	0.7025
Reduction in throughput time	0.2249***	1.0000						4.2708	0.7466		0.6728
Increase in reliability	0.1676**	0.4788***	1.0000					4.4583	0.7387		0.6704
Reduction in stock	0.0694	0.1818**	0.2030**	1.0000				4.0938	0.9742		0.7164
Increase in utilization rates	0.2811***	0.3310***	0.3394***	0.4371***	1.0000			4.0938	0.9186		0.6380
Reduction in cost	0.2616***	0.3328***	0.3683***	0.3237***	0.5489***	1.0000		4.2917	0.7802		0.6423
Feasibility of created planning	0.3878***	0.1990**	0.2428**	–0.0820	0.0859	0.2536**	1.0000	4.4479	0.6628		0.7127

**** Significant at p<0.01; ** Significant at p<0.05*

Table 7: Operational definition of *relative advantage.*

Indicators	*Factor 1: Logistics-related advantage*	*Factor 2: Package-related advantage*
Increase in utilization rates	0.775	
Reduction in cost	0.620	
Reduction in stock	0.578	
Increase in reliability	0.442	0.370
Reduction in throughput time	0.442	0.354
Feasibility of created planning		0.737
Agility of creating a planning		0.505
Cronbach's alpha	??	??
Logistics-related advantage	.831	
Package-related advantage	.024	.995

Table 8: Rotated factor matrix of *relative advantage.*

Indicators	Pearson correlation		Mean	S.D.	Cronbach's alpha
Cost of purchasing	1.0000		3.8283	0.8576	0.8951
Cost of implementation	0.8112***	1.0000	3.9697	0.8138	

**** Significant at p<0.01*

Table 9: Operational definition of *total cost of ownership.*

Indicators	Pearson correlation		Mean	S.D.	Cronbach's alpha
Vendor support during implementation	1.0000		4.5196	0.5401	0.7488
Offering of training programs by vendor	0.6079***	1.0000	4.3137	0.6446	

**** Significant at p<0.01*

Table 10: Operational definition of *vendor support.*

Indicators	Pearson correlation			Mean	S.D.	Cronbach's alpha	alpha if indicator deleted
Employees frequently visit seminars	1.0000			2.8099	1.0748	0.7797	0.6231
Employees read specialist literature	0.6240***	1.0000		3.2066	0.9909		0.7030
Employees attend logistics courses	0.5438***	0.4526***	1.0000	2.5455	0.9916		0.7669

**** Significant at p<0.01*

Table 11: Operational definition of *external communication.*

Indicators	Pearson correlation		Mean	S.D.	Cronbach's alpha
Number of different departments	1.0000				0.5631
Richness of functional differentiation	0.4157***	1.0000			

**** Significant at p<0.01*

Table 12: Operational definition of *functional differentiation.*

Indicators	Pearson correlation		Mean	S.D.	Cronbach's alpha
Organization frequently implements innovations	1.0000		3.4609	1.0112	0.7572
Implementation of innovations is generally successful	0.6202***	1.0000	3.4174	0.8375	

**** Significant at p<0.01*

Table 13: Operational definition of *innovation experience.*

Indicators	Pearson correlation			Mean	S.D.	Cronbach's alpha	alpha if indicator deleted
Number of Bachelor degrees	1.0000			2.3056	1.3075	0.7074	0.7199
Number of Master's degrees	0.5404***	1.0000		1.3426	0.7632		0.6703
Hiring external logistics consultants	0.2223***	0.1424	1.0000	1.7778	0.8790		0.6917

**** Significant at p<0.01; ** Significant at p<0.05*

Table 14: Operational definition of *professionalism.*

Construct	Adopters N	Mean rank	Non-adopters N	Mean rank	Test statistics Mann-Whitney U	Wilcoxon W	Z	Exact sig. (2-tailed)
Management support	18	81.31	101	56.20	525.5	5676.5	–3.133	0.002
Other users' opinions	18	32.89	77	51.53	421.0	592.0	–2.710	0.006
# End-products	19	82.13	109	61.43	700.5	6695.5	–2.606	0.008
Innovation	16	70.56	92	51.71	479.0	4757.0	–2.262	0.023

Table 15: Results of Mann-Whitney and Wilcoxon rank sum tests for *APS adoption.*

Construct	Adopters N	Mean	Non-adopters N	Mean
Management support	18	4.50	101	3.88
Other users' opinions	18	2.78	77	3.57
Number of end-	19	4.79	109	3.87
Innovation experience	16	3.84	92	3.37

Table 16: Means for adopters and non-adopters.

Construct	φ Value	Exact. Sig.
Planning/logistics	0.212	0.024
ERP usage	0.175	0.076
IT department	0.146	0.154
Economical condition	0.120	0.627

Table 17: *φ* values of *APS adoption* and nominal-scaled constructs.

Planning/logistics department → ↓ APS adoption	Yes		No		Total
Yes	18 (19.6)	(94.7)	1 (2.8)	(5.3)	19 (14.8)
No	74 (81.4)	(67.9)	35 (97.2)	(32.1)	109 (85.2)
Total	**92**	**(71.9)**	**36**	**(28.1)**	**128**

Frequency counts shown as cell values, with percentage of row totals and column totals given in parentheses.

Table 18: Contingency matrix of *APS adoption* and *planning/logistics department.*

Construct 1	Construct 2	Estimate	P
Innovation experience	Organizational level of	0.345	0.002
Innovation experience	External communication	0.300	0.001
External communication	Organizational level of	0.299	0.003
Agility of creating a planning	Observability	0.170	0.014
Other user's opinion	Observability	0.348	0.000
Agility of creating a planning	Feasibility of created planning	0.165	0.005
Agility of creating a planning	Innovation experience	0.274	0.004
Cost of purchasing	Cost of implementation	0.516	0.000
Management Support	Innovation experience	0.188	0.009
Management Support	External communication	0.442	0.000
Other user's opinion	APS adoption	–0.077	0.008
Cost of purchasing	APS adoption	–0.043	0.010
Management Support	APS adoption	0.064	0.003
APS adoption	Number of end-products	0.124	0.006
Size	Organizational level of	0.559	0.000

Table 19: Covariances in the measurement model of APS adoption with spurious relations.

			Total direct effect	Total indirect effect	Total effect
Other user's opinions	→	*APS Adoption*	−.26		−.26
Observability	→	*APS Adoption*		(.49) (−.26) = −.41	−.13
Number of end-products	→	*APS Adoption*	.20		.20
Cost of purchase	→	*APS Adoption*	−.22		−.22
Management support	→	*APS Adoption*	.24		.24
Innovation experience	→	*APS Adoption*		(.24) (.45) = .11	.11
External communication	→	*APS Adoption*		(.24) (.45) (.54) = .06	.06
Professionalism	→	*APS Adoption*		(.24) (.45) (.54) (.37) = .02	.02

Table 20: Total effects in the final path model.

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