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# A structural approach to assessing postponement strategies: construct development and validation

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## Abstract

This paper endeavours to introduce and validate constructs and measured variables for postponement strategies. Although empirical researchers have examined postponement, a consistent set of valid, reliable factors has not been developed and used. The lack of valid construct is a barrier to hypothesis testing and meta-analysis on postponement.

Using confirmatory factor analysis (CFA), the validity and reliability of the proposed postponement constructs are examined. This is performed through a pilot study and a large scale survey on a sample of 219 manufacturing firms which represent a wide range of manufacturing operations. The outcomes of this paper establish a set of variables which can measure shipment, manufacturing, purchasing and design postponements.

Keywords: postponement, shipment postponement, manufacturing postponement, ordering/purchasing postponement, design postponement, measured variables.

## 1. Introduction

Postponement has been recognised as an operations strategy in engineering, logistics and operations management bodies of knowledge ‘to resolve issues arising from operating in a mass customised market’ (Ismail and Sharifi, 2006). Postponement tries to manage risks and uncertainties in demand by delaying value-adding activities throughout the supply chain (Saghiri, 2008). The delay can happen in the sequence (form), time or place of activities (Yang et al. 2004a; and Wong et al., 2009). The literature contains diverse perspectives on the postponement theories and applications. There, however, is a considerable gap in measuring (measurement instruments for) postponement. In general, measurement is crucial in strategy development efforts. Measuring the level at which a postponement strategy is employed facilitates the

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evaluation of its outcomes and their links with postponement. Postponement may affect the inventory level (Davila and Wouters, 2007), inventory cost (Aviv and Federgruen, 2001), delivery lead time (Skipworth and Harrison, 2006), supply chain flexibility (Nair, 2005), responsiveness (Forza et al, 2008), and cost (Davila and Wouters, 2007). By measuring postponement, its benefits/costs can be assessed and analysed in more detail.

Moreover, various enablers and barriers may affect the success of a postponement strategy. To find their impacts, the employed postponement strategy should first be understood and measured properly. Factors such as product modularity (Yang et al., 2004b), supply chain structure (Yeung et al., 2007), and market volatility (Rabinovich and Evers, 2003) has an impact on postponement implementation. These impacts can be assessed in depth if the level of postponement can properly be measurable. This depends greatly on a valid, reliable measurement system for postponement. There are studies which indicate, for example, product modularity or process re-organisation as enablers of postponement (Yang et al., 2004a; Forza et al., 2008). They, however, fail to evaluate the effect of enablers as they cannot measure postponement implementation. Despite numerous studies on different aspects of postponement theories and applications, limited measured variables have been developed to assess postponement. Li et al. (2005) have developed general measured variables for postponement such as ‘product modular design’, ‘products customisation in distribution centres’, ‘assemble to order system’, and ‘delayed assembly to downstream stages of the supply chain’.

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3 Rabinovich and Evers (2003) introduce two constructs of 'Reliance of time  
4 postponement' and 'Reliance of form postponement' where evaluation of them has not  
5 been well clarified. In Nair (2005), manufacturing postponement is addressed by a  
6 single variable (i.e. the programmes developed to facilitate postponement of the final  
7 product manufacturing, assembly, packaging or labelling), which does not measure all  
8 aspects of postponement. Davila and Wouters (2007) measure the level of  
9 postponement by the percentage of generic products shipped across the supply chain,  
10 which is a relevant but not sufficient metric. Finally, Tang and Lau (2008) address  
11 postponement measurement. However, they only link some operational performance  
12 indicators (e.g. inventory holding) to the rate of postponement, where the rate is  
13 addressed very vaguely.  
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29 The studies reviewed above have a very narrow definition of the postponement  
30 constructs and their measured variables. They mostly focus on postponement enablers  
31 (e.g. modular design or common components) rather than purely on postponement  
32 implementation and performance. This paper tries to develop a measurement  
33 instrument for postponement. It identifies and validates postponement constructs and  
34 measured variables for each.  
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43 The rest of this paper is organised as follows. Section 2 explains the methods of  
44 identification and confirmation of the postponement constructs. Section 3 introduces  
45 the postponement constructs and their measured variables recommended by this  
46 research. Results of the pilot study are presented in section 4, and outcomes of the  
47 confirmatory factor analysis on the large scale study are discussed in section 5. Finally,  
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3 section 6 provides conclusions and recommendations.  
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## 9 **2. Methods**

### 10 **2.1 *Latent variable (LV) approach***

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12 The research constructs in many fields of study are often not directly measurable or  
13 observable. Those constructs are called 'latent variables' (Bagozzi, 1984). The latent  
14 variable approach is appropriate for this research, as the postponement constructs  
15 discussed in this study can be represented by a variety of variables. The literature of  
16 postponement has highlighted its multidimensionality. Academicians and practitioners  
17 who participated in this research also agree on the suitability of the latent variable  
18 approach for this research (see the pilot study in section 4).  
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### 32 **2.2 *Construct and scale development***

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34 This research pursues the construct and scale development process introduced and  
35 tried out in the literature (see for example Churchill Jr, 1979) with the following  
36 stages:  
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- 40 • Stage 1: Identification of the constructs and definition of their measured variables.
- 41 • Stage 2: Content validity analysis with expert judges.
- 42 • Stage 3: Scale purification and assessment of convergent and discriminant validity  
43 through the pilot study (Q-sort analysis).
- 44 • Stage 4: Assessment of convergent and discriminant validity and unidimensionality  
45 through the large-scale study and confirmatory factor analysis.  
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3 For stage 1, an extensive literature review has lead to identification of the constructs  
4 and measured variables for postponement. Considering the definitions and details  
5 provided for the research constructs in the literature, constructs in this research are  
6 originated based on the research conducted and published recently. Accordingly, this  
7 research identifies an initial list of measured variables (items) for each construct. In  
8 total, 28 measured variables and 4 constructs have been generated with 7 measured  
9 variables for each postponement construct. Each construct and its associated variables  
10 are discussed and initially validated with details (see section 3). This will be a basis for  
11 confirming the construct content validity.  
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24 After the definition of the constructs and their variables, the validation process is  
25 carried out in stages 2 to 4. Validation refers to the extent to which a construct, which  
26 is not observable, is reflected by a variable(s) that measures or manipulates that  
27 construct (Hair et al., 2006). In stage 2, the content validity is assessed by practitioners  
28 and academicians. First, through a group interview and discussion, the definition of the  
29 constructs used in this research is presented to five consultants and managers who all  
30 agreed to attend a joint meeting. The practitioners are all experts in the areas of  
31 strategy, production, logistics, purchasing, and product design. They are selected from  
32 the firms in, or related to, the sample frame of the large-scale survey (see section 2.3).  
33 Following the explanation of the basics of the study and research constructs, initial  
34 variables of each postponement construct have been introduced and discussed.  
35 Variables that are not agreed to belong to the domain of each construct are removed,  
36 new variables are recommended and other items are modified if required.  
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In the second part of the content validation process, copies of the postponement constructs definitions and the associated variables have been distributed to eight faculty members in fields of operations and supply chain management, and five have replied. They could recommend changes in the construct definition and variables. This includes adding or deleting variables of each construct. If changes are major, academicians are requested to appoint a time for an interview to discuss the details. The major changes are also double-checked with the managers involved earlier in the content validation.

In stage 3, the convergent and discriminant validity of the postponement constructs are assessed through the pilot study and the Q-sort method (Nahm et al., 2002). The Q-sort method is an iterative process for manual factor sorting by judges. The degree of judges' agreement on the variables allocated to each construct, forms the basis of assessing construct validity. In each iteration, the constructs' variable pool is provided to two judges who are chosen from the managerial level of companies of the sample frame or from experts who work with the sample frame companies. They have a good knowledge and understanding of the theories and practices of operations and supply chain management. The current research and previous stages are briefed to them, and their questions are answered. Judges are not the same in different iterations. This process is done through face-to-face meetings or via email communication. Two tables on separate sheets are provided to the judges. The first table lists the research constructs and their abbreviations (i.e. shipment postponement: SP, manufacturing postponement: MP, ordering/purchasing postponement: OP, and design postponement: DP) and the second table lists the recommended measured variables (in no particular



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3 order) with a blank box in front of each. Judges are supposed to allocate the measured  
4 variables to one of the research constructs by writing SP, MP, OP or DP in the blank  
5 box or just writing n/a (not available) if they believe the variable is not related to any  
6 of the constructs. The level of agreement between judges is measured by two methods;  
7 Cohen's Kappa (Cohen, 1960) and Moor and Benbastas hits ratio (Moor and  
8 Benbastas, 1991). Cohen's Kappa is measured as the agreement proportion of joint  
9 judgment after the chance agreement is excluded from it. Cohen's Kappa is calculated  
10 as  $(\sum_i P_{ii} - \sum_i P_{i+} P_{+i}) / (1 - \sum_i P_{i+} P_{+i})$  where  $P_{ij}$  is the percentage of agreement/disagreement  
11 between two judges (see Nahm et al. (2002) for the details). The value of Kappa is  
12 between zero and one. Values between 0.40 and 0.75 are usually recognised as fair to  
13 good, and values more than 0.76 show an excellent degree of agreement (Landis and  
14 Koch, 1977; Moor and Benbastas, 1991). The hit ratio in Moor and Benbastas method  
15 is calculated as  $\sum_i P_{ii} / \sum_{ij} P_{ij}$  where  $P_{ij}$  are agreed/disagreed items and  $P_{ii}$  are agreed items  
16 (see Nahm et al., 2002, for details). Hit ratio is good if it is more than 65%. (Sethi and  
17 King, 1994). At the end of each iteration, details of judgments are discussed and  
18 necessary changes (i.e. deletion of measured variable or change of wording) are made.  
19 The iterative process is carried out until the variables allocated to the constructs are all  
20 agreed – i.e. good Cohen's Kappa and hit ratio are achieved. Details of application and  
21 results of the Q-sort method are discussed in section 4.

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48 In stage 4, the large-scale study is conducted by means of confirmatory factor  
49 analysis (CFA) to analyse the convergent and discriminant validity. There is a general  
50 understanding in the literature that the construct validity largely depends on  
51 convergent and discriminant validity and constructs unidimensionality (Carmines and  
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3 Zeller, 1979). CFA is used based on the strong theory provided by the literature, which  
4 supports the postponement constructs and their associated measured variables. CFA is  
5 recognised as a useful tool with high capability to examine the construct validity and  
6 proposed measured variables (Campbell and Fiske, 1959; Hair et al., 2006).  
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12 Data required by CFA in the large-scale study is collected via 219 usable  
13 questionnaires (details are discussed in section 2.3). Considering the medium size of  
14 the sample, CFA in this study uses the partial least square (PLS) method (Tenenhaus et  
15 al. 2005). Convergent validity of the postponement constructs are assessed by separate  
16 LV1→LV1<sup>1</sup> models, and unidimensionality and discriminant validities are measured  
17 in paired LV1→LV2 models (see Tenenhaus et al. 2005 for details). Figure 1 shows  
18 the research structure and the main outcomes of each stage.  
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### 29 30 **2.3 Sampling process and questionnaire design**

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33 The sample frame for the large-scale study consists of 593 manufacturers (suppliers) of  
34 a wide range of automotive parts and components – the unit of study is the individual  
35 firm/company. According to the ISIC Rev. 3.1<sup>2</sup> (UN, 2009), the sample frame covers  
36 divisions 17, 25, 26, 27, 28, 31, 32, and 34 of section ‘D’<sup>3</sup>. All companies in the  
37 sample frame are small and medium-sized companies. Although the sample frame is  
38 limited to automotive suppliers, it represents the majority of manufacturing industries.  
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47 The target respondents in the firms (i.e. units of study in the sample frame) are senior  
48 or middle managers in the areas of operations, purchasing, logistics, quality,  
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52 <sup>1</sup>. LV: Latent Variable.

53 <sup>2</sup>. The International Standard of Industrial Classification of all economic activities.

54 <sup>3</sup>. The codes address manufacture of textiles, rubber and plastic products, other non-metallic mineral  
55 products, basic metals, Manufacture of fabricated metal products, except machinery and equipment,  
56 manufacture of electrical machinery and apparatus n.e.c., radio, television and communication  
57 equipment and apparatus, motor vehicles, trailers and semi-trailers, and manufacturing ISIC groups of  
58 products.  
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3 production or strategic management. Beside their job position, it is assured that they  
4 have both theoretical and practical knowledge of their job as well as the context of the  
5 current study (i.e. operations strategy and postponement).  
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10 After three rounds of attempts<sup>4</sup> (including reminder emails, letters and telephone  
11 contacts), 219 usable questionnaires have been collected. 58 usable questionnaires  
12 have been returned after the first round, 92 usable questionnaires have been returned  
13 after the second round, and 69 usable questionnaires have been returned after the third  
14 attempt. This indicates a response rate of 36%, which is satisfactory and comparable  
15 with similar studies (for example, Das, 2001: 19%; Koste et al., 2004: 11.5%).  
16 Moreover, Power analysis, as the most accurate way to identify the sample size and its  
17 power, is also employed (McQuitty, 2004; Faul, 2008). The sample size of 219 and  $\alpha$   
18 = 0.05 in a two-tail assessment have resulted in an extremely high power of 0.99 for a  
19 medium effect size ( $r = 0.30$ ) and 0.85 (high) and 0.6 (almost high) for the effect size  
20 of 0.20 and 0.15 respectively. Similarly, the multiple regression omnibus test under the  
21 F-tests in G\*Power, with sample size of 219 and  $\alpha = 0.05$  indicates high power of  
22 0.81, 0.93 and 0.99 for  $r = 0.15$ , 0.2 and 0.3 respectively. Hence, the sample size of  
23 219 is appropriate for the structural analysis by PLS in this research.  
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44 Concerning the missing values, returned questionnaires with multiple missing  
45 values have been dropped (seven cases). However, those with one or two non-  
46 responded questions have been kept. As a result, as few as eight missing values exist in  
47 the research data pool. Missing values are given the value of '-1', and PLS then  
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57 <sup>4</sup>. Follow ups are done six and ten weeks after the initial submission.  
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3 handles them using the case-wise replacement technique before it starts the estimation  
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5 process.  
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8 Concerning the non-response bias in responses, the extrapolation method  
9 recommended by Armstrong and Overton (1977) is followed. The first wave of  
10 responses is compared with those responses received after follow-ups (which are  
11 considered as non-responses). A random sample of 30 responses is taken from each  
12 group, and possible difference between them is tested by the t-test for difference  
13 between the two samples for each single measured variable. The results indicate no  
14 significant difference at  $\alpha = 0.05$  level. Details can be collected from the author.  
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24 Possible differences among different groups of respondents are also assessed.  
25 Usable responses are divided based on two criteria: (i) response mode/channel  
26 (manual/hard copy vs. electronic/email) and (ii) the industry group to which a firm  
27 belongs (ISIC Group). The t-test for difference between the two samples indicates no  
28 significant difference between postal/ hard copy and electronic responses at  $\alpha = 0.05$   
29 level. Responses of the firms, which belong to different industry groups are also  
30 classified into eight groups (ISIC groups: 17, 25, 26, 27, 28, 31, 32, and 34). The  
31 difference among those responses is assessed by ANOVA test. The results indicate no  
32 significant difference among the groups. The results are available from the author.  
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46 The questionnaires developed for the large-scale study mainly address the  
47 postponements' measured variables (see Table 2) and try to find the application level  
48 of the measured variables of the postponement constructs<sup>5</sup>. Questions are grouped into  
49 four sets which represent the four postponement constructs. Each question addresses  
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58 <sup>5</sup>. Details of the questionnaire can be collected from the author.  
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3 one measured variable (of those which passed the pilot study, as listed in Table 3) and  
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5 tries to find to what extent it is employed by the firm. Two examples of questions are  
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7 as follows:  
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10 MP2: Describe the percentage of manufacturing/assembly activities (in your firm)  
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12 which are postponed by the time more accurate information from the customer is  
13  
14 received (choices: <20%; 21-40%; 41-60%; 61-80%; and 81-100%).  
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17 MP3: Describe the amount of manufacturing/assembly work (in terms of time) which  
18  
19 is postponed, compared to total time spent in manufacturing (choices: <20%; 21-  
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21 40%; 41-60%; 61-80%, and 81-100%).  
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24 The questions try to quantify the measured variables in different ways, such as  
25  
26 using the five-point Likert scale (Sethi and King, 1994). The Likert scale assures the  
27  
28 reliability of the questionnaire very well (Mitchell, 1996). Reliability is also examined  
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30 through the *test re-test* method (Bracken and Barona, 1991) which is applied to a small  
31  
32 group of randomly selected respondents. The answers are coded as '1' to '5' where '1'  
33  
34 and '5' indicate the lowest and highest level of a postponement measure respectively.  
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37 To assess the questionnaire validity, it has been pre-tested and reviewed by three  
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39 academicians to discover any ambiguity in the questions, possible complexity in  
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41 understanding the questions, problems regarding logical sequences or relations  
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43 between questions, the time requirements to complete the questionnaire, comments on  
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45 the contents, and comments on the structure of the questionnaire.  
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### 3. Postponement typology, constructs and measured variables

This section first reviews different classifications provided by the literature for postponement. This helps initial identification of postponement constructs and measured variables. A list of postponement constructs and their measured variables are then proposed. Content validity of the recommended constructs is also discussed with expert judges. These form the construct and scale development's stages 1 and 2.

#### 3.1 *Postponement: diverse types and classifications*

Various types of postponement have been defined and addressed in the literature. Having a review of the postponement definitions in literature (see for example taxonomical studies by Van Hoek, 1998 and Yang et al., 2004b), postponement typologies can be classified into three groups: (i) classification according to the function of postponement; (ii) classification according to the stage of the value-adding process in the supply chain; and (iii) classification according to the scope of products covered by the postponement strategy.

The first type of postponement classification categorises postponements according to their main function or purpose. Van Hoek (1998) discusses that postponement can occur in form, time or place. He defines form postponement as delaying activities which determine the function and form of the products until receiving more information about the demand. 'Delay' is addressed vaguely in this definition. If it referred to delay in terms of time, it would be the definition of time postponement, whether it is about product differentiation or non-differentiation activities. Form postponement is mainly about moving the activities towards supply chain downstream (Forza et al., 2008; Shao and Ji, 2008), which is not necessarily linked to time and

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3 place. Van Hoek (1998) defines time postponement as delaying activities which do not  
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5 determine the function and form of the products until receiving more information  
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7 about the demand. This definition has shortfalls as it tries to discriminate between  
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9 activities which do and do not determine the function and form of the products, and to  
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11 link the second group to the time postponement. This is not always true as time  
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13 postponement can be applied to differentiation activities as well. Van Hoek's (1998)  
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15 definition of place postponement refers to delaying the flow of material towards the  
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17 supply chain downstream until receiving more information about the demand. Again,  
18  
19 this definition is mixed up with time postponement (when it refers to 'until receiving  
20  
21 more information'). In place postponement, one or more activities are performed in a  
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23 place nearer to the market, and could be coupled with time and form postponement.  
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30 In this type of postponement classification (based on the postponement function),  
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32 Lee (1998) introduces 'pull postponement', 'logistics postponement' and 'form  
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34 postponement' as the three main categories of postponement. By pull postponement,  
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36 Lee means moving the customer order decoupling point (Sharman, 1984) closer to the  
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38 customer. By logistics postponement, Lee (1998) implies doing some operations  
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40 further along the supply chain. And by form postponement, he means changing the  
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42 sequence of activities which form the product and/or move the differentiation activities  
43  
44 towards supply chain downstream. Form postponement has been defined similarly in  
45  
46 other studies (for example see Skipworth and Harrison, 2004 and Forza et al., 2008).  
47  
48 Lee's (1998) definition of logistics postponement is mainly linked with moving the  
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50 place of one or some operations. In that respect, the concept of time postponement has  
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52 been missed in his classification. In many cases, time postponement is not linked with  
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3 place. In other words, time postponement may occur at one stage (or place) of the  
4 supply chain (not moving activities from one stage to the other). In his categorisation,  
5 Lee (1998) links postponement to customer order decoupling point (pull  
6 postponement) where these two concepts are not directly equivalent or necessarily  
7 linked (Van Hoek, 2001).

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15 Similar discussions may apply to other studies which partially consider form,  
16 logistics, time and place postponement. Pagh and Cooper (1998) explain that ‘logistics  
17 postponement’ is performed ‘by direct distribution of fully finalised products from a  
18 centralised inventory to final retailer/customer.’ In their classification, logistics  
19 postponement refers to time and place. Conversely, Van Hoek (1998) and Bowersox,  
20 et al. (1999) distinguish and discuss two categories of ‘time postponement’ and ‘place  
21 postponement’. As a conclusion for this type of classification, form, time and place  
22 postponements can be recognised as the main categories of this classification.  
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34 The second type of postponement classification categorises postponements, based  
35 on the stage in the supply chain (the value-adding activity) where the postponement  
36 occurs, or based on the state of inventories that Yang et al. (2007) define. Many  
37 studies have addressed postponement in production processes (e.g. Waller et al.,  
38 2000). Zinn and Bowersox (1988) provides a good explanation of postponement in  
39 production processes and discuss that postponement may happen at labelling,  
40 packaging, assembly and manufacturing stages. This classification of postponement is  
41 restricted to the in-house production processes. Even in the context of production  
42 processes, although this classification comprises the main operations, other activities  
43 of a production system such as storage and transport could have been considered for  
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postponement. Yang et al. (2004a) discuss that postponement may happen in the 'logistics', 'production', 'purchasing' or 'product design and development' stages. This classification is useful as it clarifies the type of value-adding activity which is delayed. However, it does not explain whether the postponement is in time, form or place. Figure 2 summarises the literature of this classification.

<Insert Figure 2 here>

In the third type of classification, postponements are categorised based upon the number of products covered by the postponement. While all products are covered by the postponement strategy, it is called full postponement. However, when only some products or parts of a product demand are postponed, it is called 'partial' or 'hybrid postponement' (Graman and Magazine, 2006). Lee (1998) uses the same labels ('partial' and 'full') for different types of postponement. Although this classification is not comprehensive, it may help define postponement measured variables.

### 3.2 *Postponement constructs and initial measured variables*

As reviewed earlier, there are very few measured variables recommended and developed for postponement in the literature. Even those mentioned by the literature are mostly vague and inaccurate. Table 1 indicates the postponement measures used in the literature.

<Insert Table 1 here>

As shown by Table 1, the measured variables recommended in the literature are either very indistinct (i.e. general measures) or not directly measuring postponement

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3 (i.e. product-based measures). For example, although assemble to order configuration  
4 or modular design of a product may support postponement, they do not measure the  
5 level at which postponement is employed. In view of that, this study concentrates on  
6 measuring postponement directly.  
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12 To address postponement directly and measure it precisely, this fundamental  
13 question should be answered first: *postponing of what?* The literature mentions the  
14 postponement of manufacturing, assembly, packaging, purchasing, shipment, and the  
15 like. The common factor among all those operations is value. In fact, postponement in  
16 the context of operations management is about delaying one or some value-adding  
17 activities. Hence, to define postponement constructs and their measured variables, this  
18 study tries to find what type of values are delayed, how many of them are delayed,  
19 how much they are delayed by, and so on. Moreover, as postponement is about delay,  
20 measuring postponement is linked with measuring the time-length of postponement  
21 and duration of the postponed operations.  
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36 In this respect, the current research considers the value-adding activities, which  
37 move the product closer to the form or location desired by the customer, and the  
38 relevant delays throughout the supply chain. The main value-adding activities of a  
39 supply chain may consist of purchasing, production and distribution (Chen and Paulraj,  
40 2004). Bowersox et al. (2010: p. 6) define supply chain primary activities as  
41 procurement, manufacturing, customer accommodation and distribution. Yang et al.  
42 (2004a) identify a wider range of main activities including product design, purchasing,  
43 production and shipment. Similarly, Simchi-Levi et al. (2009: p. 4) highlight the main  
44 elements of supply chain as design, sourcing, production, distribution and sale.  
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3 Consistent with the literature, this study focuses on four main value-adding activities  
4 of the supply chain: product design, purchasing (including sourcing, ordering and  
5 procurement), manufacturing (including main production of components, assembly,  
6 packaging, labelling, etc.) and shipment (including distribution). Accordingly, it  
7 defines four constructs for postponement: *shipment postponement* (SP), *manufacturing*  
8 *postponement* (MP), *ordering/purchasing postponement* (OM) and *product design*  
9 *postponement* (DP). The selected postponement typology addresses the value-adding  
10 operations and includes aspects of form, time and place postponements. In shipment  
11 postponement, the value is in moving the product to a closer location desired by the  
12 customer. Companies may limit their distribution channels, centralise their stock  
13 points and delay shipment of products to the next stage of the supply chain (e.g. retail  
14 shops or customers' home address) until they receive more accurate information about  
15 the demand. In general, there should be less cost in keeping the inventory in a  
16 centralised warehouse than the supply chain downstream (e.g. a high street retail  
17 shop). Moreover, by making more accurate shipments, the over-stock cost will be  
18 reduced and the lead-time or stock-out costs may be increased. The cost and benefits  
19 of shipment postponement should be analysed in each case independently, and  
20 measurement of the shipment postponement facilitates that analysis. In manufacturing  
21 postponement the product is held unfinished in a general status which gives more  
22 flexibility, less inventory cost and less risk of obsolete finished goods. The  
23 manufacturing postponement largely depends on the configuration of the product and  
24 the production process. By having the right measure for manufacturing postponement,  
25 its enablers and barriers can be explored in more detail. In design and purchasing  
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postponement, the value is in developing the right product and procuring the right material. Delaying these value-adding activities, manages the risk of mismatch between customer desire and the value generated to meet it at source. Design and purchasing postponement are critical activities which affect an extensive number of operations across the supply chain. Their impacts can be examined appropriately when they are measured more accurately. Considering the above explanations, measured variables of the postponement constructs are defined as follows.

As postponement is about delaying activities before anything else, the first measured variable of postponement is the *length of time of the postponement*. The more the activity is delayed in terms of time, the higher the level at which the postponement strategy is implemented. The impact of the time length of postponement and its effect on cost/benefit of postponement strategy has been outlined by Lee and Tang (1997). This measure is shown by  $l$  in Figure 6. So when  $l=0$ , no postponement happens. An activity can be delayed by the time the real customer order arrives. This will be an upper limit for  $l$ . To reflect postponement status in a firm as a whole, rather than for individual activity or product, the average of delays in postponements which are applied to activities/products are considered as a measured variable.

The second suggested variable is the *number or share of activities which are delayed*. The higher the number of delayed activities (compared to the total number of activities for a particular operation), the more the postponement strategy is put into operation. This variable is shown by  $n/N$ , where  $n$  is the number of delayed activities and ' $N$ ' is the total number of activities. For instance, when out of ten main purchasing

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3 activities, two of them (for example, specifying the purchasing items' requirements  
4 and releasing the order) are delayed, the design postponement measure is 0.2.  
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8 The third measured variable for postponement strategy can be the *overall size (in*  
9 *terms of the time) of activities which are delayed* (i.e. total duration of the delayed  
10 activities). The larger the duration of the delayed activities, the higher the level of  
11 postponement. This variable is shown by  $d$  in Figure 4. A small  $d$  indicates the  
12 postponement of short activities, a large  $d$  specifies the postponement of lengthy  
13 activities, and the latter one represents a higher level of postponement. The rationale  
14 for choosing this variable is based on the role we expect from postponement to  
15 mitigate the risk. If lengthy activities are done in advance (not postponed) and the  
16 output product does not match the customer order which arrives later, lengthy rework  
17 may be required. To alleviate this risk, more work (in terms of the operation time) can  
18 be delayed. This measure can be considered firm-wide (not only for one product or  
19 operation), when the average of durations (of the postponed activities) is worked out.  
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36 For the fourth variable, the *value of, or the value added by, the postponed activities*  
37 is focused upon (Lee and Tang, 1997). The more the adding value is delayed the  
38 higher the level of postponement is employed. The fourth variable is defined based on  
39 the similar rationale provided for the third variable, where instead of time, the value  
40 added by activities is considered. This variable is shown by  $v$  in Figure 6.  
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48 The fifth suggested variable is the *percentage or share of products which follow the*  
49 *postponement strategy*. The higher the number of products included in postponement  
50 strategy, the more the postponement strategy is deployed in an operations system. This  
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3 variable can be shown by shown by  $m/M$ , where  $m$  is the number of products included  
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5 in postponement strategy and  $M$  is the total number of products.  
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8 The sixth variable is suggested as the *percentage or share of customers for which*  
9  
10 *postponement strategy is pursued*. Expansion of postponement strategy for a wide  
11  
12 range of customers indicates the high level of implementation of postponement  
13  
14 strategy. This variable can be shown by  $c/C$ , where  $c$  is the number of customers  
15  
16 included in postponement strategy and  $C$  is the total number of products.  
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20 The seventh recommended variable refers to the *deployment of the postponement*  
21  
22 *strategy in the planning activities*. The more the postponement is considered in the  
23  
24 firm's planning, the higher the level of postponement implementation is expected. The  
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26 highest level would apparently be when postponement is maintained in the strategic  
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28 planning of a firm. Figure 6 summarises the recommended measure variables for  
29  
30 postponement.  
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35 <Insert Figure 6 here>  
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38 Based upon the seven measured variables developed for postponement in general,  
39  
40 the measured variables for each type of postponement are identified in Table 2.  
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44 <Insert Table 2 here>  
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#### 46 **4. Pilot Study**

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49 In this section, the measured variables suggested for the postponement constructs  
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51 (Table 2) are initially assessed by a pilot study for convergent and discriminant  
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53 validity. As explained earlier in section 2.2, Q-sort method is used to pre-assess the  
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55 convergent and discriminant validity.  
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In the first round of the pilot study, following the Q-sort method, the overall hits ratio of 68%, the inter-judge raw agreement ratio of 79%, and the Cohen's Kappa score of 73% have been achieved, which are all moderate or good. In order to improve the hits ratio and agreement scores, off-diagonal entries in the Q-sort matrices are reviewed. Feedback from the two first-round judges is also considered. As a result, two variables from DP (DP6 and DP7), two variables from OP (OP6 and OP7), one variable from MP (MP7), and one variable from SP (SP7) have been removed. The modified variables are then entered into the second round.

Two different judges participate in the second round. The results have shown a good improvement in overall hits ratio. At the end of the second round, the overall hits ratio is 95%, the inter-judge raw agreement ratio is 91%, and the Cohen's Kappa score is 88%. All the ratios are interpreted as a good level of agreement. To improve the ratios, the feedback of the judges in the second round has been discussed and the modified set of variables has been entered into the third round (MP6 and SP6 have been dropped). Two new judges take part in the third round. They receive a brief clarification on variables and details of their definition. At the end of round three, the overall hits ratio is improved to 98%, the inter-judge raw agreement ratio is 95%, and the Cohen's Kappa score is 93%. All figures are improved and variables placement is confirmed. Measured variables of each postponement construct (outcomes of the pilot study) are listed in Table 3. By the end of pilot study stage, the dropped variables in all constructs (i.e. SP6, SP7, MP6, MP7, OP6, OP7, DP6 and DP7) are related to *the percentage of customers for whom postponement is applied to their products, and the level of deployment of postponement in the firm's planning task*. The discussions with

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3 the judges who have participated in the pilot study indicate that linking the dropped  
4 variables with postponement and measuring them is very difficult (if possible at all).  
5  
6 For example, finding the number of customers to whom postponed manufacturing is  
7 applied changes continuously. Similarly, understanding how postponement as a  
8 strategy is deployed across the firm and affects its plans is almost impossible (at least  
9 in the sample frame of this research).  
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17 <Insert Table 3 here>  
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## 20 21 **5. Confirmatory factor analysis**

### 22 23 24 **5.1 Convergent validity and reliability analysis**

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26 This section runs the CFA process for each construct and its associated variables. An  
27 LV1→LV1 measurement model is developed for each construct, measured variables'  
28 loadings are calculated by PLS, and convergent validity is discussed accordingly. In  
29 the case of low loading, i.e. less than 0.7, the measured variable with low loading is  
30 reviewed with one academician and one practitioner (from those people who have been  
31 involved in the pilot study). Then, the measured variable with low loading is deleted  
32 (after agreeing on it), and the CFA process is run again for the construct. This iterative  
33 process is carried out until the construct with all significant loadings ( $\geq 0.7$ ) results.  
34 Cronbach's Alpha measures are also calculated to measure the constructs' reliability.  
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#### 49 **5.1.1 CFA: design and development postponement (DP)**

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51 The CFA results for the product design postponement (DP) construct indicates a low  
52 loading (0.596) for DP4 (i.e. the amount of design and development work in terms of  
53 value it makes/adds, which is postponed, compared to total value made on design and  
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3 development). After discussion on this measured variable, it has been found that the  
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5 variable is very difficult to understand and measure. Moreover, some aspects of it exist  
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7 in DP3 (i.e. the amount of design and development work in terms of time which is  
8  
9 postponed compared to the total time spent on design and development). By removing  
10  
11 this variable, major theoretical aspects of DP construct are still kept. Thus, DP4 is  
12  
13 deleted. This improves the convergent validity. All other loadings in the first round of  
14  
15 CFA have been high. In the second round, all loadings are high. Hence, the DP  
16  
17 convergent validity is confirmed. Two rounds of CFA are shown in Table 4. Hence,  
18  
19 four measured variables, DP1, DP2, DP3 and DP5 are passed to the next stage  
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21 (discriminant validity assessment).  
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28 *<Insert Table 4 here>*  
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### 30 31 *5.1.2 CFA: ordering/purchasing postponement (OP)*

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33 The CFA results for the ordering/purchasing postponement (OP) construct indicates  
34  
35 high loading for all measured variables except one which is 0.388 for OP4 (i.e. The  
36  
37 amount of ordering work - in terms of value it makes/adds, which is postponed,  
38  
39 compared to the total value made in ordering). After discussion on this measured  
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41 variable, it has been found that the variable is very difficult to understand and measure.  
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43 Moreover, some aspects of it exist in OP3 (i.e. the amount of ordering work in terms of  
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45 time, which is postponed, compared to the total time spent in ordering). So, by  
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47 removing this variable, major theoretical aspects of the OP construct are still kept.  
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49 Thus, it has been decided to delete OP4. This improves the convergent validity of OP.  
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53 The second round of CFA indicates high loadings for all measured variables. Hence,  
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55 the OP convergent validity is confirmed. Two rounds of CFA are shown in Table 5.  
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3 The high average variance extracted (AVE) and Cronbach's Alpha measures also  
4 indicate the high validity and reliability of the OP measurement model. Hence, four  
5 measured variables, OP1, OP2, OP3 and OP5 are passed to the next stage  
6 (discriminant validity assessment).  
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13 <Insert Table 5 here>  
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#### 16 17 5.1.3. CFA: manufacturing postponement (MP)

18 The CFA results for the manufacturing postponement (MP) construct indicates high  
19 loadings for all measured variables. Results are shown in Table 6. Also, the high AVE  
20 and Cronbach's Alpha measures indicate the high validity and reliability of the MP  
21 measurement model. Hence, five measured variables, MP1, MP2, MP3, MP4 and MP5  
22 are passed to the next stage (discriminant validity assessment).  
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#### 35 5.1.4. CFA: shipment postponement (SP)

36 The CFA results for the shipment postponement (SP) construct indicates high loading  
37 for all measured variables except one, which is 0.412 for SP4. After discussion on this  
38 measured variable, it has been found that the variable may be very difficult to interpret  
39 and measure. Moreover, SP3 may cover some aspects of it, and by removing SP4,  
40 major theoretical aspects of the SP construct are still kept. Thus, it has been decided to  
41 delete OP4. This improves the convergent validity of SP. The second round of CFA  
42 indicates high loadings for all measured variables. Hence, the SP convergent validity is  
43 confirmed. Two rounds of CFA are shown in Table 7. The high AVE and Cronbach's  
44 Alpha measures also indicate the high validity and reliability of the OP measurement  
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3 model. Hence, four measured variables, OP1, OP2, OP3 and OP5 are passed to the  
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5 next stage (discriminant validity assessment).  
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9 *<Insert Table 7 here>*  
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## 11 **5.2 CFA: Discriminant validity and unidimensionality**

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13 Discriminant validity is tested by comparing the square of the correlation between two  
14  
15 constructs and the average variance extracted (AVE) of each construct (Chin and  
16  
17 Newsted, 1999). If the variance extracted is higher than the squared correlation, the  
18  
19 discriminant validity test is passed. Moreover, unidimensionality is assessed through  
20  
21 cross-loadings analysis. A high cross-loading may indicate that a measured variable  
22  
23 does not belong to the construct which it is supposed to. To make those assessments,  
24  
25 all research constructs and their variables, which have been confirmed earlier, pass a  
26  
27 dual comparison process. The process consists of forming an LV1→LV2 path model  
28  
29 and calculating AVE, correlation and cross-loadings. Table 8 and Table 9 show the  
30  
31 results. The path model diagrams are also provided in Appendix A. As indicated in  
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33 Table 8, all AVEs are higher than the associated correlations. Beside, no significant  
34  
35 cross-loading is found in Table 9 which confirms the constructs' unidimensionality.  
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44 *<Insert Table 8 here>*  
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47 *<Insert Table 9 here>*  
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50 Passing the convergent validity and discriminant validity assessment through the  
51  
52 CFA process in this section, the final postponement constructs and measured variables  
53  
54 are DP (DP1, DP2, DP3, DP5), OP (OP1, OP2, OP3, OP5), MP(MP1, MP2, MP3,  
55  
56 MP4, MP5), SP (SP1, SP2, SP3, SP5).  
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### 5.3 *Implication of the results*

The confirmatory factor analysis arrives at a list of validated measured variables for the postponement constructs identified by this research. There are some variables which have been dropped during the pilot study and the confirmatory factor analysis. These final variables are not necessarily exclusive, but reflect postponement measures to a reliable extent. The results indicate that all four postponement constructs are measured by the *duration of the delay*, *durations of the delayed activity*, *share of the delayed activities* (compared to all activities), and *share of the products postponement applied to them* (compared to all the firm's products). For the manufacturing postponement, *value of the delayed activity* should also be added to the measured variables. This has been highlighted (not been dropped) for the manufacturing postponement as there is not necessarily a direct link between the duration and the value of an activity in manufacturing processes. Moreover, measuring the value of manufacturing activities is much easier than design, ordering or shipment activities. Thus, when the postponement is considered at the activity level in design, ordering/purchasing or shipment operations, it can be measured by two key variables: *duration of the delay* and *duration of the delayed activity*. So the postponement level of a product design activity, as an example, depends on how lengthy the activity is and how long it is delayed. For manufacturing postponement, *value of the delayed activity* should also be considered. To measure postponement at a higher level, which includes all activities of a specific stage of the value chain (e.g. product design or shipment), *share of the delayed activities* is also considered as a postponement measured variable. Finally, to expand the postponement measurement instrument to a firm-wide scale,

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3 *share of the products postponement applied to them* should be added to the other  
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5 variables.  
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## 8 9 **6. Discussion and Conclusions**

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11 The main objective of this research was to develop valid and reliable constructs for  
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13 postponement. Four domains of postponement have been identified based on the  
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15 literature review. Seven measured variables have been developed for each construct  
16  
17 and their validity and reliability have been tested systematically. The content validity,  
18  
19 reliability, unidimensionality, convergent validity and discriminant validity, have been  
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21 assessed through a pilot study and a large-scale study using Q-sort method and  
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23 confirmatory factor analysis.  
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28 Based on the results, the four postponement constructs – i.e. *shipment* (SP),  
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30 *manufacturing* (MP), *ordering/purchasing* (OM) and *product design* (DP) - have  
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32 content validity. As indicated by the values of Cronbach's alpha, all postponement  
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34 constructs are reliable. High measured variables' loadings, communalities and AVEs  
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36 in CFA indicate convergent validity of the constructs and their final measured  
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38 variables. Moreover, non-significant correlations between the constructs compared to  
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40 AVEs approves the discriminant validity. Finally, very low cross-loadings support the  
41  
42 unidimensionality of the constructs and proposed measured variables. The results  
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44 indicate that the research objective has mostly been accomplished and the  
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46 postponement constructs can be used confidently in future studies. The contribution of  
47  
48 the research outcomes and their significance are discussed in the rest of this section.  
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54 The literature of postponement indicates that postponement is not measured directly  
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56 and appropriately. The four postponement constructs and their measured variables  
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3 validated in this paper represent a conceptualisation for postponement measurement.  
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5 Many empirical studies of postponement have addressed indirect measures for  
6  
7 postponement (as shown in Table 1). Davila and Wouters (2007) use product  
8  
9 configuration factors such as generic components to measure postponement. Li et al.  
10  
11 (2005) similarly use product modular design as a postponement measure. They also  
12  
13 refer to delaying processes such as assembly to articulate postponement. Other studies  
14  
15 such as Nair (2005) use very general measures such as ‘programmes developed to  
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17 facilitate postponement’ to evaluate postponement. The validated postponement  
18  
19 constructs and measured variables proposed by this research concentrate directly on  
20  
21 postponement, not on its enabler, barriers or impacts. Consistent with that, the  
22  
23 validated postponement constructs and their variables address postponement in three  
24  
25 levels of single activity, main operations (group of activities), and the whole firm.  
26  
27 Proposing and rigorously validating constructs and measured variables for  
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29 postponement is the main contribution of this paper. Moreover, measuring  
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31 postponement in multiple layers is the second contribution of this research. The  
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33 instrument developed in this paper is practical. It can be of use to researchers for  
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35 further studies of postponement practices, in the context of operations and supply  
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37 chain management, and their relationships with other operations strategies and  
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39 operational performances. The development of the measurement instrument for  
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41 postponement is expected to motivate and facilitate further theory development and  
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43 testing in this field.  
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53 The validation of the postponement constructs also has important implications for  
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55 managers. Identification of the level at which a postponement strategy is employed is  
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3 crucial to examine the factors affecting postponement and postponement impacts on  
4 other performance factors. Although there are many studies on influencing factors on,  
5 or impacts of, postponement (for example Nair, 2005; Yang et al., 2005; Davila and  
6 Wouters, 2007; Shao and Ji, 2008), there are extremely limited measures developed or  
7 suggested for postponement (Rabinovich and Evers, 2003; Nair, 2005). Even the few  
8 suggested measures for postponement are very rough and limited. By developing and  
9 validating postponement constructs and their measured variables, this paper has  
10 contributed significantly to the postponement practical body of knowledge. When a  
11 postponement strategy is measurable, its link with performance factors on which it  
12 may have impact (e.g. flexibility) can be examined more efficiently. For example, in  
13 an E-tailing system, shipment to the customer's home address is postponed until the  
14 customer's online order arrives. To find the impact of postponement on the inventory  
15 cost in the distribution centres and retail shops, the postponement level should be  
16 measured. The measurement instrument developed in this paper can identify the extent  
17 to which shipment postponement is employed. It measures the shipment duration, the  
18 time length of the delay in shipment, the shipment activities which are delayed and the  
19 products the postponement applies to them. By measuring those variables, the level of  
20 postponement is determined more accurately. Then, the link between shipment  
21 postponement and inventory cost can be evaluated analytically and in more detail.

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48 Considering the research findings and limitations, there are opportunities for  
49 research in future. This research has arrived at some measured variables for four  
50 postponement constructs. The measured variables are the result of a validation process  
51 which has been conducted on the initial list of variables (Table 2). The postponement  
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3 dimensions extracted from the literature on postponement and the final validated  
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5 variables can be re-tested by future studies. Although the current results can be a  
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7 useful tool to measure postponement, future studies may conduct a further  
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9 confirmatory analysis in other sample frames. Separate case studies can also test the  
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11 suitability and relevance of the postponement measured variables for industries which  
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13 have not been addressed in this study. This will provide a comprehensive set of  
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15 postponement measured variables for operations strategists and managers. Finally,  
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17 although the sample size has been sufficient for the structural model analysis (PLS  
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19 analysis) and has passed the power analysis test, the larger sample which covers  
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21 multiple industrial sectors supports the generalisation of the results.  
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## 30 **7. Acknowledgment**

31  
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34 and supportive comments.  
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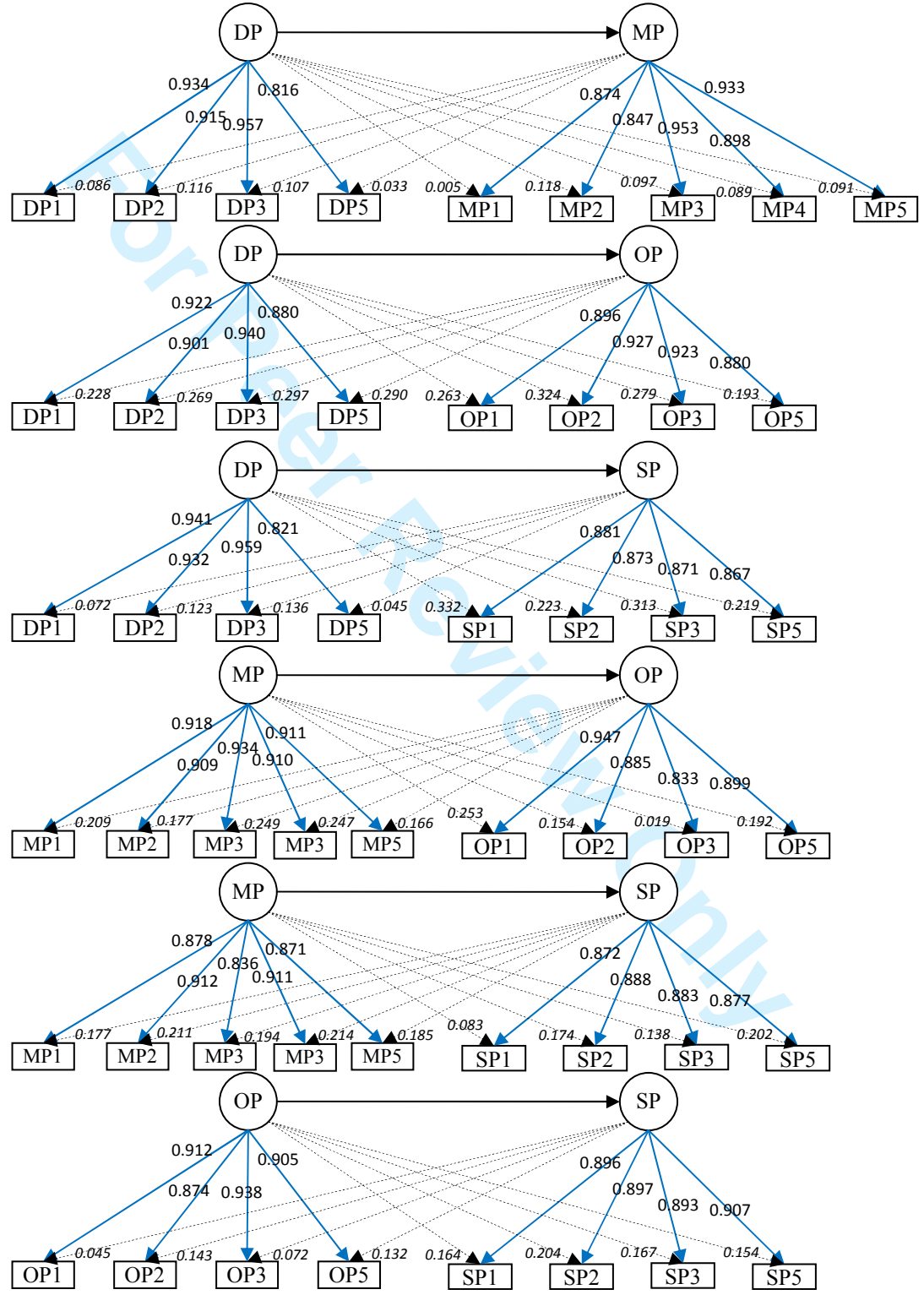
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### Appendix A CFA: Measurement Models for the Research Constructs Discriminant Validity (loadings and cross-loadings)



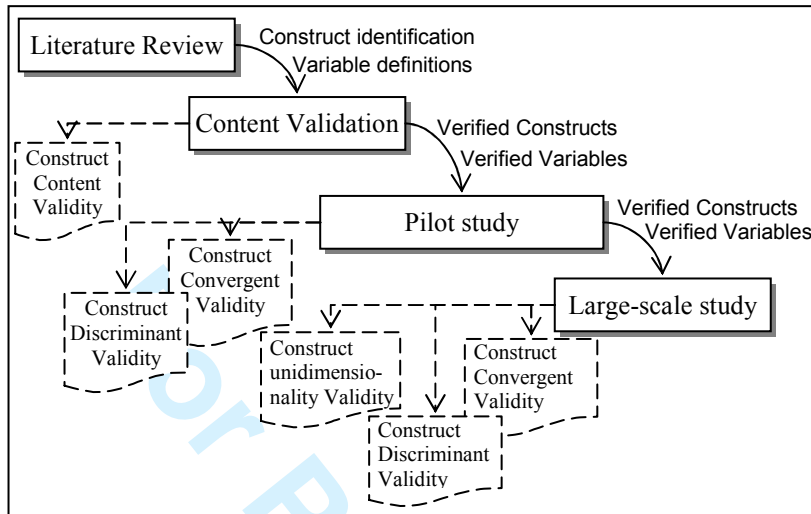


Figure 1. The overall structure of the construct validity assessment.



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<i>Supply Chain Stage:</i>	<i>Product Development</i>	<i>Ordering / Purchasing</i>	<i>Manufacturing / Assembly</i>	<i>Packaging / Labelling</i>	<i>Shipment / Logistics</i>
Zinn and Bowersox, 1988			✓ ✓*	✓ ✓**	
Lee, 1998			✓		✓
Pagh and Cooper, 1998			✓		✓
Battezzati and Magnani, 2000			✓		✓
Yang et al., 2004a	✓	✓	✓		✓

\* Manufacturing & Assembly postponements are introduced separately. \*\* Packaging & Labelling postponements are introduced separately.

Figure 2. Postponement classification strategies based on their implementation in different supply chain stages.

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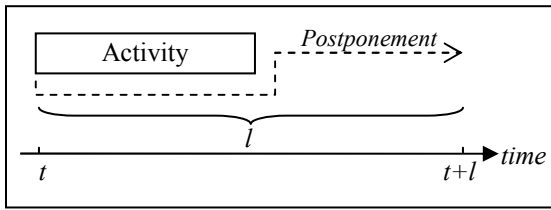


Figure 3. Postponement in terms of time length of the delay ( $l$ ).

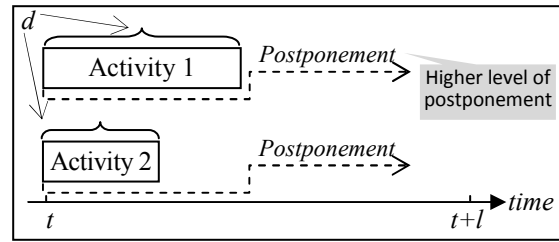


Figure 4. Postponement in terms of time length of the delayed activity ( $d$ ).

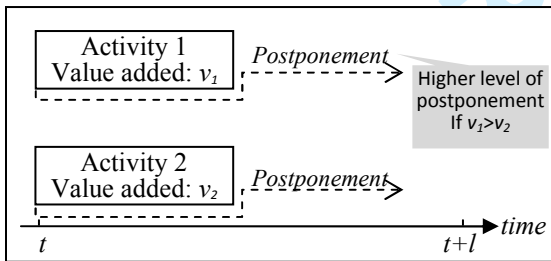


Figure 5. Postponement in terms of value of the delayed activity ( $v$ ).



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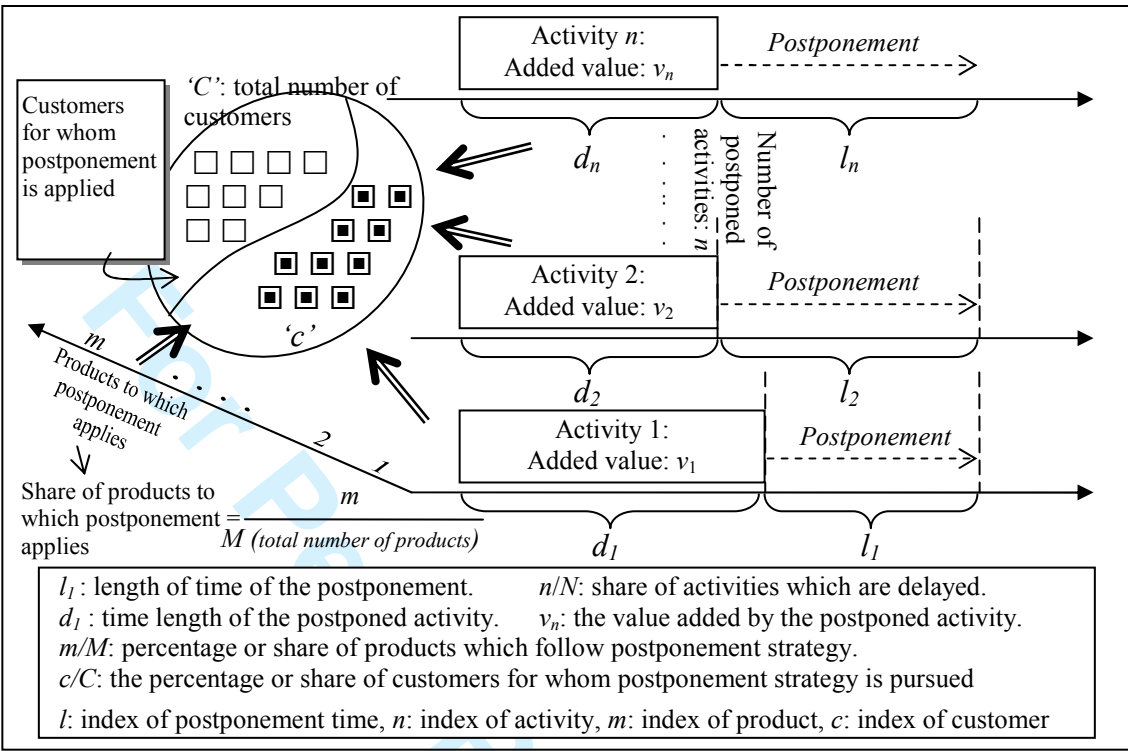


Figure 6. Six measured variables for postponement (note the seventh variable - deployment of the postponement strategy in company planning activities, is not shown in this figure).

Table 1. A summary of postponement measured variables recommended by the literature.

<i>Product-based Measures</i>	<i>General Measures</i>
Li et al. (2005): - Product modular design - Products customisation in distribution centres - Assemble to order system - Delayed assembly to the supply chain downstream Davila and Wouters (2007): - The percentage of generic products shipped across the supply chain	Rabinovich and Evers (2003): - Reliance of time postponement - Reliance of form postponement Nair (2005): - The programmes developed to facilitate postponement Tang and Lau (2008): - Rate of postponement

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Table 2. Proposed postponement constructs and measured variables.

<b>Construct</b>	<b>Measure Variable</b>
Product design postponement (DP):	<p>DP1: Average postponement time in development of a new product or modification of the design of an existing product (the postponement time varies between the <i>no delay</i> (lowest postponement level) and <i>delay until receiving customer order</i> (highest postponement level)).</p> <p>DP2: The percentage of product design and development activities which are postponed.</p> <p>DP3: The amount of design and development work (in terms of time) which is postponed (compared to the total time spent on design and development).</p> <p>DP4: The amount of design and development work (in terms of value it makes/adds) which is postponed (compared to total value made in the product design and development).</p> <p>DP5: Percentage of products, postponement applies to their design and development process.</p> <p>DP6: Percentage of customers for whom design and development postponement is applied to their product.</p> <p>DP7: Level of deployment of postponement in the firm's design and development planning tasks.</p>
Ordering postponement (OP):	<p>OP1: Average postponement time in ordering purchasing items – i.e. raw materials or components (the postponement time varies between the <i>no delay</i> (lowest postponement level), and <i>delay until receiving customer order</i> (highest postponement level)).</p> <p>OP2: The percentage of ordering activities which are postponed.</p> <p>OP3: The amount of ordering work (in terms of time) which is postponed (compared to the total time spent in ordering operations).</p> <p>OP4: The amount of ordering work (in terms of value it makes/adds) which is postponed (compared to the total value made in ordering operations).</p> <p>OP5: Percentage of products, postponement applies to their ordering operations.</p> <p>OP6: Percentage of customers for whom ordering postponement is applied to their product(s).</p> <p>OP7: Level of deployment of postponement in the firm's ordering planning tasks.</p>
Manufacturing postponement (MP):	<p>MP1: Average postponement time in manufacturing (the postponement time varies between the <i>no delay</i> (lowest postponement level), and <i>delay until receiving customer order</i> (highest postponement level)).</p> <p>MP2: The percentage of manufacturing processes which is postponed.</p> <p>MP3: The amount of manufacturing work (in terms of time) which is postponed (compared to total time spent in manufacturing).</p> <p>MP4: The amount of manufacturing work (in terms of value it makes/adds) which is postponed (compared to total value made in manufacturing).</p> <p>MP5: Percentage of products, postponement applies to their manufacturing processes.</p> <p>MP6: Percentage of customers for whom manufacturing postponement is applied to their product.</p> <p>MP7: Level of deployment of postponement in the firm's manufacturing planning tasks.</p>
Shipment postponement (SP):	<p>SP1: Average postponement time in shipment (the postponement time varies between the <i>no delay</i> (lowest postponement level), and <i>delay until receiving customer order</i> (highest postponement level)).</p> <p>SP2: The percentage of shipment operations which is postponed.</p> <p>SP3: The amount of shipment (in terms of time) which is postponed (compared to total time spent in shipment).</p> <p>SP4: The amount of manufacturing work (in terms of value it makes/adds) which are postponed (compared to total value made in shipment).</p> <p>SP5: Percentage of products, postponement applies to their shipment.</p> <p>SP6: Percentage of customers for whom shipment postponement is applied to their product.</p> <p>SP7: Level of deployment of postponement in the firm's shipment planning tasks.</p>

Table 3. The postponement constructs and variables: outcomes of the pilot study.

<i>Construct</i>	<i>Variable</i>	<i>Construct</i>	<i>Variable</i>	<i>Construct</i>	<i>Variable</i>	<i>Construct</i>	<i>Variable</i>
DP:	DP1	OP:	OP1	MP:	MP1	SP:	SP1
	DP2		OP2		MP2		SP2
	DP3		OP3		MP3		SP3
	DP4		OP4		MP4		SP4
	DP5		OP5		MP5		SP5

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Table 4. CFA process for the design & development postponement (DP) construct.

Round	Items	Loadings	Commuality	AVE	Cronbach's Alpha
1	DP1	0.930	0.865	0.721	0.897
	DP2	0.889	0.791		
	DP3	0.932	0.869		
	DP4	0.596	0.355		
	DP5	0.853	0.727		
2	DP1	0.931	0.867	0.831	0.932
	DP2	0.900	0.811		
	DP3	0.942	0.888		
	DP4	0.870	0.756		
	DP5	0.870	0.756		

Table 5. CFA process for the ordering/purchasing postponement (OP) construct.

Round	Items	Loadings	Commuality	AVE	Cronbach's Alpha
1	OP1	0.897	0.804	0.681	0.865
	OP2	0.899	0.808		
	OP3	0.904	0.818		
	OP4	0.388	0.151		
	OP5	0.908	0.824		
2	OP1	0.897	0.804	0.824	0.929
	OP2	0.910	0.829		
	OP3	0.922	0.849		
	OP4	0.901	0.812		
	OP5	0.901	0.812		

Table 6. CFA process for the manufacturing postponement (MP) construct.

Round	Items	Loadings	Commuality	AVE	Cronbach's Alpha
1	MP1	0.919	0.845	0.841	0.953
	MP2	0.915	0.837		
	MP3	0.930	0.865		
	MP4	0.899	0.809		
	MP5	0.921	0.849		

Table 7. CFA process for the shipment postponement (SP) construct.

Round	Items	Loadings	Commuality	AVE	Cronbach's Alpha
1	SP1	0.917	0.841	0.665	0.806
	SP2	0.872	0.760		
	SP3	0.864	0.747		
	SP4	0.412	0.170		
	SP5	0.885	0.783		
2	SP1	0.932	0.869	0.806	0.907
	SP2	0.889	0.790		
	SP3	0.876	0.767		
	SP4	0.891	0.794		
	SP5	0.891	0.794		

Table 8. Assessment of discriminant validity: comparing AVE and correlation square.

Path Model	Correlation <sup>2</sup>	Construct	AVE	AVE > Correlation <sup>2</sup>
DP-MP	0.01	DP	0.82	YES
		MP	0.81	YES
DP-OP	0.09	DP	0.83	YES
		OP	0.82	YES
DP-SP	0.02	DP	0.82	YES
		MP	0.81	YES
MP-OP	0.06	MP	0.84	YES
		OP	0.80	YES
MP-SP	0.08	MP	0.81	YES
		SP	0.81	YES
OP-SP	0.02	OP	0.81	YES
		SP	0.81	YES

Table 9. Research constructs cross-loadings – unidimensionality analysis.

	DP	MP		DP	OP		DP	SP
DP1	0.934	0.086	DP1	0.922	0.228	DP1	0.941	0.072
DP2	0.915	0.107	DP2	0.901	0.269	DP2	0.932	0.123
DP3	0.957	0.116	DP3	0.94	0.297	DP3	0.959	0.136
DP5	0.816	0.033	DP5	0.88	0.290	DP5	0.821	0.045
MP1	0.005	0.874	OP1	0.263	0.896	SP1	0.332	0.881
MP2	-0.018	0.847	OP2	0.324	0.927	SP2	0.223	0.873
MP3	0.097	0.953	OP3	0.279	0.923	SP3	0.313	0.871
MP4	0.089	0.898	OP5	0.193	0.880	SP5	0.219	0.867
MP5	0.091	0.933						
	MP	OP		MP	SP		OP	SP
MP1	0.918	0.209	MP1	0.878	0.177	OP1	0.912	0.045
MP2	0.909	0.177	MP2	0.912	0.211	OP2	0.874	0.143
MP3	0.934	0.249	MP3	0.836	0.194	OP3	0.938	0.072
MP4	0.910	0.247	MP4	0.911	0.214	OP5	0.905	0.132
MP5	0.911	0.166	MP5	0.871	0.185	SP1	0.164	0.896
OP1	0.253	0.947	SP1	0.083	0.872	SP2	0.204	0.897
OP2	0.154	0.885	SP2	0.174	0.888	SP3	0.167	0.893
OP3	-0.019	0.833	SP3	0.138	0.883	SP5	0.154	0.907
OP5	0.192	0.899	SP5	0.202	0.877			