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Abstract

Project execution in the construction industry faces major challenges, e.g. difficulty in coordination and cooperation. Operational procurement during project execution is no exception. In this paper we construct a maturity model, based on earlier work, consisting of six dimensions (goal, control, process, organization, information, technology) and five maturity stages (transactional-oriented, commercial-oriented, coordination, internal-optimized, external-optimized). The model can be used to determine the level of procurement maturity for each of the dimensions, and for the determination of a strategy for growth in the construction industry. With input from a major construction firm in the Netherlands, through simulating tooling, the model is evaluated for its contribution to growth in operational excellence. Results of the simulation show support for a relation between maturity growth and increased operational excellence.

Keywords: Procurement, Business/IT-Alignment, Simulation

1 Introduction

The construction industry is the prime example of a project-based industry in which firms can be characterized by project-oriented processes, one-off products, decentralized project teams, and complex cross-functional, inter-organizational relationships (e.g. Bresnen, Goussevskaia & Swan, 2004; Bresnen & Marshall, 2000; Gann & Salter, 1998, 2000; Hobday, 2000). In project-oriented processes, *operational procurement* is playing a crucial role as it sets the basis for coordination and cooperation among project participants (Egan, 1998; Korczynski, 2007; Olsen et al., 2005). Operational procurement consists of the actual ordering, receiving and payment of goods or services (van Weele, 2005).

Existing research results on the procurement function in general has identified *maturity growth* on *several dimensions* -including organizational structure, control, process and IT- as a useful strategy for addressing the improvement of this function (Batenburg & Versendaal, 2008; Beukers et al., 2006; Cousins, Lawson & Squire, 2006; Paulraj, Chen, & Flynn, 2006; Schiele, 2007). The maturity approach provides not only the dimensions that help to assess the organization, but also the stages that outline the evolution path of improvements over time (Becker, Knackstedt & Pöppelbuß, 2009). The maturity-performance link represents the underlying hypothesis of our paper and originates from the Strategic Alignment model of Henderson and Venkatraman (1993) Their assumption was that increased maturity as for IT does not, per se, increase a firm's productivity; a propor alignment with other aspects in the firm is necessary. Many other scholars have since then operationalized this concept. Specifically, Beukers et al. (2006), and Batenburg and Versendaal (2008) have applied the concept of business/IT-alignment in the domain of procurement in general; in this paper we observe the maturity-performance link regarding *operational procurement* in the construction industry. As optimizing *operational* procurement is much related to efficiency, we decide to define performance through operational excellence measurements (Treacy & Wiersema, 1996).

The objective of this paper is the determination of an operational procurement maturity growth model for the Project-Based Construction (PBC) industry which contributes to operational excellence.

In this paper we create an operational procurement maturity model for the PBC-industry. Considering the model as a design artifact, we follow the research method as defined in the Information System Research Framework (Hevner et al., 2004). The construction of the model is based on past research on procurement maturity/alignment and takes the generic model of Batenburg & Versendaal (2008) as a starting point.

Following this section, we first provide background information on the PBC-industry. Subsequently the outline of the conceptual model is constructed. The operationalization of the model is performed with the help of explorative interviews and literature study. The initial version of the model is validated through a simulation with input from one of the major construction firms in the Netherlands. We conclude with an approach for operational procurement maturity growth and suggestions for further research.

2 Research background

In this section we elaborate on the characteristics and trends of the PBC-industry, and we define an outline for the maturity-based conceptual model.

2.1 Project-Based Construction industry characteristics

The PBC-industry has particular characteristics as can be found in literature; table 1 lists the details.

Characteristic	Definition
Project-oriented processes	Core business processes, such as design, production and procurement processes are organized around projects rather than functional departments (Gann & Salter, 1998, 2000; Hobday, 2000).
One-off products	Products that are produced as a result of the specific scenarios and conditions of a certain project. (Bresnen, Goussevskaia & Swan, 2004).
Decentralized project teams	Project teams are not centrally dispatched creating considerable horizontal and vertical distinction within individual construction companies and a high level of separation between project activities and broader corporate strategies (Bresnen & Marshall, 2000; Dubois & Gadde, 2002).
Cross-functional and inter-organizational contractual and working relationships	The relationship is built with coordination and cooperation of specialists of different professional background who take responsibility of different parts of a project and follow diverse institutional norms defined within an organization or by another party of the supply chain (Dubois & Gadde, 2002; Bresnen, Goussevskaia & Swan, 2004).

Table 1: Construction Industry Characteristics

Also, the PBC-industry is subject to many challenges, which can be considered industry specific, general business challanges and operating environment challanges (Toor and Ofori, 2006). *Vertical consolidation* is considered necessary by Thiry & Deguire (2007) between the project-level and organizational-level management. Yitmen (2007) has ranked *culture* in the construction industry as the top driver of changes. In the construction industry the *adoption of ICT*, as a driver for facilitating information flow, is recognized from a process and organizational practices point of view by Rankin & Luther (2006). Gann & Salter (2000) also suggest improving the *control* over time, budget and quality of construction projects as a drive of change. The impact of *IT usage* appears next to culture on the list of the observation carried out by Yitmen (2007), as a supportive tool for enhancing coordination between project participants, enabling cost saving and streamlining operational processes. Specifically *E-procurement* offers opportunities for the purchasing function and the procurement process (Croom & Brandon-Jones, 2007; de Boer, Harink & Heijboer, 2002). The drivers of change and their implications for the PBC-industry are summarized in the first two columns of table 2.

2.2 Conceptual model outline

We choose to take the generic and validated procurement framework of Batenburg & Versendaal (2008) as a starting point for our objective to determine an operational procurement maturity model for the PBC-industry (see figure 1). We are confirmed in our choice as we can easily map the drivers of change identified in section 2.1 onto all of the rows of the framework of Batenburg and Versendaal. The third column of table 2 shows this mapping.

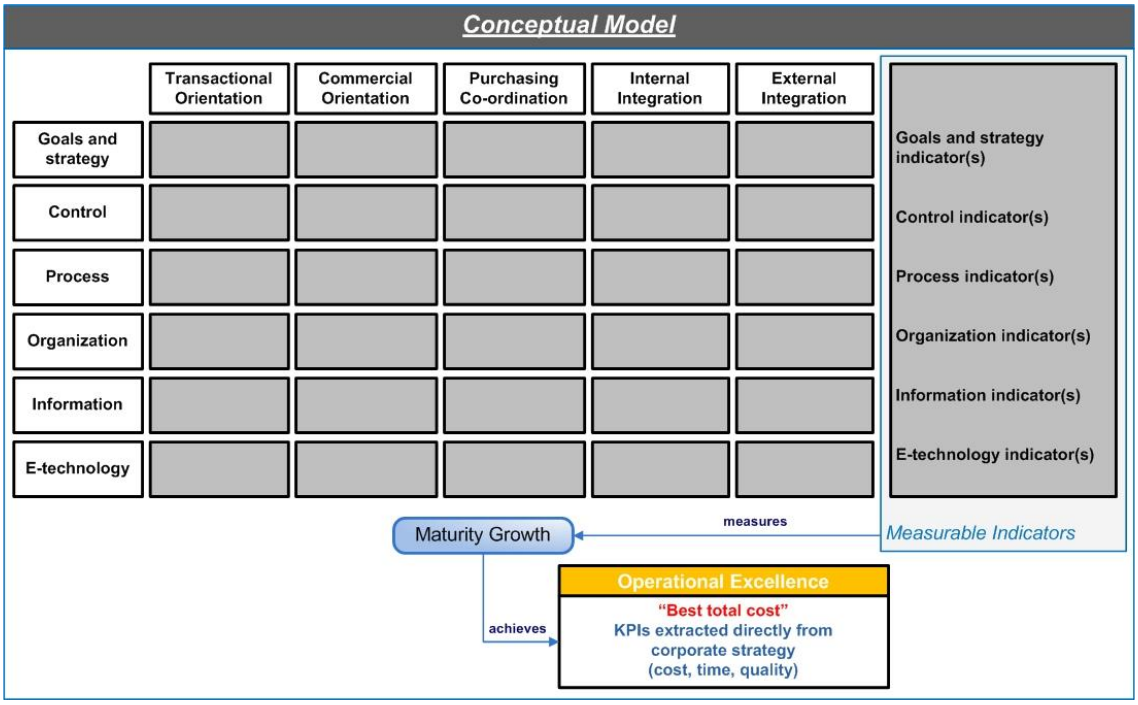

Figure 1: Outline of Operational Procurement Maturity Model for PBC industry

Drivers of Change	Implications in the PBC-industry	Related dimension in the model
Vertical consolidation (Thiry & Deguire, 2007)	Aligns the project goal and process with the organizational ones	Goal, Process
Culture (Yitmen, 2007)	Affects organizational structure, project process and control to improve performance on both daily and long-term manner	Organization, Process, Control
Adoption of ICT (Rankin & Luther, 2006)	Facilitates exchange of information from a process and organizational practices point of view	Information
Control of project (Gann & Salter, 2000)	Improves the control over time, budget and quality of construction projects	Control
IT usage (Yitmen, 2007)	Enhances coordination between project participants, enables cost saving and streamlines operational processes	Control, Process, E-technology
E-procurement (Eadie, Perera & Heaney, 2010)	Offers opportunities for the purchasing function and the procurement process	E-technology, Information

Table 2: Drivers of change in the PBC-industry and their relation to the maturity model dimensions

3 Model Operationalization

In operationalizing the framework, and making it specific for our purposes, we take the existing operationalization of the model of Batenburg & Versendaal (2008) with additional literature and practices (specifically Stalenhoef et al., 2007; Capgemini, 2008; Schiele, 2007; Cheng et al., 2010; Versendaal & Brinkkemper, 2003) and with the characteristics (table 1) and drivers of change (table 2) in order to define measurable indicators of the independent part of our maturity model. E.g. for the *process* dimension, the *process-related* measurable indicators are 'maturity of the ordering process', 'maturity of the receiving process', and 'maturity of the payment process'. Furthermore, the maturity stages are inherited from its original to address the growth potential over time. In essence, the headers of columns and rows (black fonts in white cells) and the position of the columns in figure 1 are taken from Batenburg & Versendaal (2008). In the context PCB industry, the operationalization of the grey cells in the operational maturity matrix in figure 1, the indicators in table 3 and the validation of maturity-performance link in chapter 4 are delivered in this paper.

Table 3 shows all defined measurable indicators per dimension in the maturity model.

Measurable Indicator
Goal
Operational procurement objective
Control
Contract compliance
Budget control
Process
Ordering process
Receiving process
Payment process
Organization
Procurement governance structure
Training for operational procurement activities
Project team format
Information
Availability of mechanisms to analyze transactional data
Accuracy and timeliness of information
Standardization of data format and process level
E-technology
Degree of system integration
Sophistication of data process and network technology

Table 3: Defined measurable indicators

The performance indicators are extracted from operational excellence. Operational excellence is one of the value disciplines introduced by Treacy & Wiersema (1996). It aims at ‘best total cost’ by operating in an optimized supply chain, with standardized operation and central control, and completing transactions quickly, reliably and in an integrated manner. From the original model of Batenburg & Versendaal (2008) we adopt the time, cost and quality performance indicators. These are made specific for the PBC-industry: procurement cycle time (e.g. Minahan & Degan, 2001), transaction costs (e.g. Clemens, Reddi & Row, 1993), and information quality (e.g. Monczka et al., 1998).

Through explorative interviews the model was further completed. Three respondents from three different construction firms with a procurement expert profile participated. The interviews were conducted by following the process improvement approach (as examplified by Brinkkemper et al., 2008) which suggests the desired change in maturity requires one or more changes in the process. Thus the *process* dimension was assessed first (checking the maturity of each of the *process-related* measurable indicators) and used as the existing maturity level. For this, a maturity questionnaire was constructed, combining the operationalized matrix in figure 1 with the list of measurable indicators in table 3. For example the first indicator in table 3, the question is “In our organization, with regard to operational procurement objectives we have” and the description of each maturity stage of this dimension is used as a possible answer to the question. Assessment was done by respondents answering the maturity questionnaire to determine on which level the operational procurement of the PBC company was.

The further operationalization was subsequently carried out vertically in the matrix of figure 1, revealing values for the other measurable indicators. The horizontal exploration followed by examining the evolvements from history and looking forward to future improvements. For example, when the procurement *process* maturity level of a respondent's construction firm was determined *purchasing co-ordination*, subsequently *commericial orientation* (historical exploration) and *internal integration* (future improvements exploration) processes were defined. During the simulation (section 4), a major construction company in the Netherlands, Ballast-Nedam, provided specific input for modeling the operationalized maturity model in the simulation environment.

Find below (figure 2) the operationalization of part of the *process* description for the PBC-industry on *purchasing coordination level* as highlighted with orange on the top of the figure. As implied by the highlight, there is a process chart for each maturity stage. Other charts are not illustrated in this paper for the sake of simplicity. The process-related measurable indicator payment process is depicted as the major blue box. Yellow activities identify exception handling; red-green coloured activities are semi-automated and white activities are carried out manually.

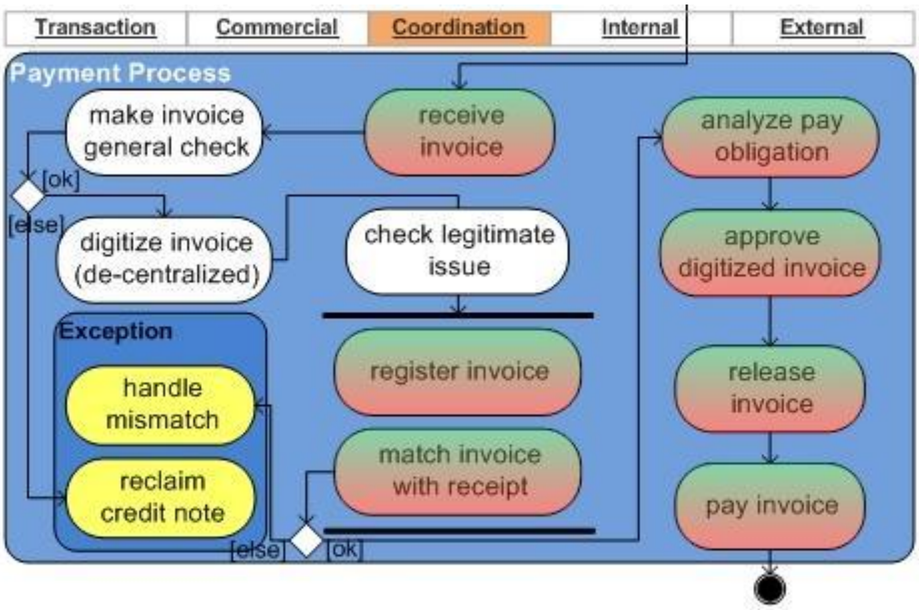

Figure 2: The *payment process* measurable indicator of the Process dimension on *purchasing coordination* maturity level (chart notation is following the meta-process diagram defined by Weerd & Brinkkemper (2008))

4 Model validation through simulation

The maturity-performance link identified in this paper is validated by discrete-event simulation. Simulation is a widely used operations research and management science technique. Through simulation, researchers can evaluate both the quantitative (performance) properties of a system with analytical or numerical modelling and qualitative (behavioural) properties with structural or process modelling (Pooley, 2007). In discrete-event simulation, a system is modelled by a state (representing the situation at a fixed moment in time), which will be changed at specific moments in time by the occurrence of events. A common modelling paradigm in discrete-event simulation is to describe the system as a network of servers and queues. This paradigm is perfectly suited to model the work flow of the procurement process of a particular firm from the PBC-industry. Ballast Nedam, a major Dutch construction firm, provided the data for our simulation; they recently changed the procurement function within the company, and therefor can provide more easily longitudinal data as simulation information. A discrete-event simulation model usually includes entities that are subject to uncertainty and hence modelled by stochastic variables. In our case, this includes arrival times of deliveries, processing times and availability of certain services required in the process.

To measure the influence of maturity growth on the operational procurement performance with respect to operational excellence as indicated by the 'achieves' arrow in figure 1, in the simulation we evaluate the following three performance measures: transaction cost, operational procurement cycle time and information quality. The current maturity of the procurement process at Ballast Nedam is assessed as level purchasing co-ordination during the year 2009, which is defined as scenario S09. This is compared to the process in 2002, denoted by scenario S02, which assessed at level commercial orientation. The scope of the simulation is the part of the operational procurement process which starts from "register receipt" and ends with "ready for pay". This part of the process does not include the lead time which is determined by the process and policy of the supplier. The process is depicted in figure 3 and is the simulation tool specific Ballast Nedam configuration of figure 2; this basic outline of the process is identical for both scenarios (S02 and S09). There are three states of the products that are flowing in the process namely: receipt(1), matched invoice(2), mismatch(3). In S09, e-technology has been implemented, including an electronic procurement system for work-planning and execution, and an extension of the ERP system with a combination of e-informing (see de Boer, Harink & Heijboer, 2002). This results in different processing times and server availability in certain parts of the process. If the server is a human person the time until s/he is available to start a job is significantly larger than in case the server is a computer.

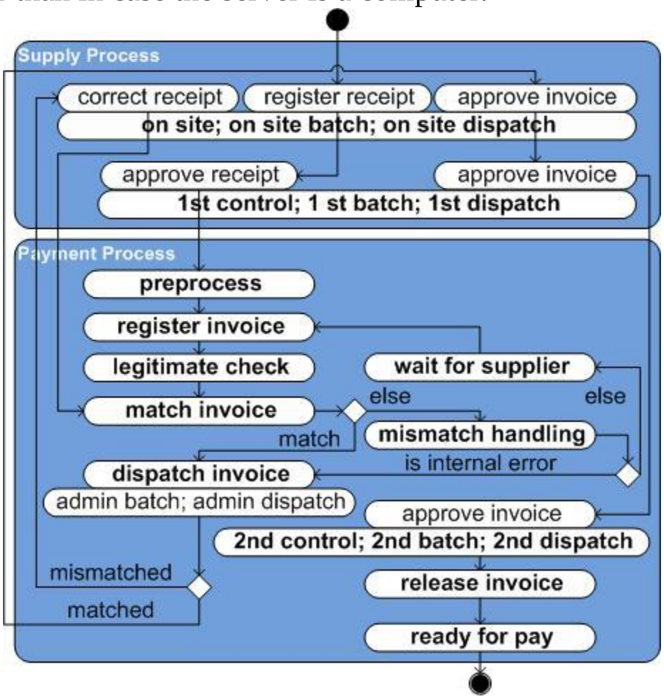

Figure 3: Ballast Nedam's modelled Procure-to-Pay process

For reasons of brevity, we will not describe all steps here. An important step is to write an "Assumptions Document", which has been agreed upon with the principal providing the input for the simulation (Ballast Nedam). The most important assumptions are the following:

1. As input probability distributions we used a) the exponential distribution for inter-arrival time of deliveries, b) the normal distribution for processing times, and c) the uniform distribution for delay time caused by waiting for the server to be working on the type of work required in the step of the process (cf. Ostle et al., 1996).

2. Computer system breakdown and network failure are exceptional and not included in our simulation study. Exceptional routines, including sick leaves, project disasters, supplier bankruptcies although occasional in reality, are not included in the simulation for simplicity.

3. The same amount of on-site, 1st control and 2nd control capacity are used to simplify the comparison in performance measurement.

4. There is no capacity limit for requesting a new invoice from suppliers. The delay is supposed to distribute equally between 3 days and 3 weeks.

5. Mismatching is assumed to be handled with only one round of investigation and fixing. Multiple rounds occurring in the real life is not simulated.

6. The average number of receipts and invoices are taken as the number of transactions. No specific waiting time for invoice arrival.

We performed our simulation and analyzed the results with the software tool Enterprise Dynamics (ED). The activities provided in figure 3 are the processing units and are modelled as servers in ED. For the different scenarios S02 and S09 they have different processing times and availability patterns. Before each server, there is a queue where products and documents are waiting to be processed.

In our experiment we performed 20 simulation runs designed for both scenarios. The 20 runs in the experiment are separate runs, each of which starts with a warm-up period to get rid of initialization effects, followed by one observation period. Using the method of separate runs, the observation periods are independent. The observation length is one year for each run with the warm up time to be 180 hours.

5 Research Results

5.1 Transaction Cost

The measured average workload of the servers, in terms of the number of products being processed, is used as bases to calculate the personnel salary and the postal costs. The columns in Table 4 show the average workload of each server during the simulation.

The '0.43' for in the column 'workload' for `on-site registration' indicates that the average amount of products which is either a receipt (state 1) or invoice (state 2 or 3) being processed by each available server (person) is 0.43 per hour. If there is a service capacity of 18, the process is modelled in the simulation by 18 parallel servers and it follows that the total processing power required is 18 times 0.43 which equals 7.74. This is represented in the columns `amount' and `total'. The underlined dispatch related atoms and the "wait for supplier" atom however are calculated differently. The dispatch related servers need a large processing time (around 8 hours), but during this time they can process all receipts that were available for processing at the same time. The `wait for supplier' is purely an artificial delay and will be omitted from the further calculation.

		S02			**S09**	
	workload	**amount**	**total**	**workload**	**amount**	**total**
on-site registration	0.43	18	7.74	0.68	18	**12.24**
on-site batch	0	1	0	0	1	0
on-site dispatch	114.74			0.02		
1st control	0.15	18	2.7	0.16	18	**2.88**
1st batch	0	1	0	0	1	0
1st dispatch	94.9			0.02		
2nd control	0.05	1	0.05	0.06	1	**0.06**
2nd batch	0	1	0	0	1	0
2nd dispatch	0.49			0.01		
preprocess	0.3	2	**0.6**	0.22	1	0.22
register invoice	1.1	5	5.5	0.25	2	0.5
legitimate check	0.11	1	0.11	0.42	1	**0.42**
match invoice	1.05	4	4.2	0.27	2	0.54
mismatch handling	0.25	1	0.25	0.02	1	0.02
wait for supplier	43.1			48.45		
admin batch	0	1	0	0	1	0
admin dispatch	67.74			0.01		
release invoice	0.02	1	0.02	0.01	1	0.01

Table 4: Simulation Procure-to-Pay process

The numbers written non-bold implicate an overall decrease of required processing capacity in S09 compared to S02; numbers in bold (4 functions) indicate an increase. From the exceptional 4 functions, the on-site registration and legitimate check require more processing in S09 than in S02. This longer processing time is due to more receipt registration details and stricter EU working regulations required for these two functions respectively. The absolute differences in 1st control and 2nd control are not considered to be significant. Except for the "wait for supplier" and dispatching functions, the functions are analyzed in two groups. Observe that the dispatching functions have a very strong time reduction from S02 to S09. One group is indicated in the green box in table 4 and outlines the decentralized (on-site related) part of the construction team. The total processing power of S09 is 15.12 and 10.44 for S02. The functions in the other groups are performed at central administration based and show a decrease from 10.73 in S02 to only 1.77 in S09. Summarizing, our simulation suggest a strong efficiency increase which may result in a large reduction of administration personnel. The overall personnel reduction per transaction in the simulation is thus 4.28, from 21.17 in S02 to 16.89 in S09 (see figure 4). In Ballast Nedam northwest subsidiary, a personnel cutback in administration from 9 to 4.5 was realized, while the decentralized personnel numbers depend on the number and scale of projects. This suggests that the simulation reflects realistic effects.

Transaction Cost	ICT (SW+HW) Investments	Support per year	Maintenance per year	Depreciation per year	Total cost per year	Personnel Gross Salary per year	Postal Cost per year
on-site related						€ 40,000.00	€ 3,600.00
System A	€ 336,000.00	€ 50,000.00	€ 8,500.00	€ 67,200.00	€ 125,700.00	Personnel Reduction total	
administration based						"(S02) - (S09) = 21.17 - 16.89"	
System B	€ 350,000.00	€ 25,000.00	€ 93,000.00	€ 70,000.00	€ 188,000.00	4.28	
Cost						Reduction	
Company Total	€ 686,000.00			per year	€ 313,700.00	€ 171,200.00	€ 3,600.00
Subsidiary Total	€ 114,333.33			per year	€ 52,283.33	€ 85,600.00	€ 1,800.00
					Balance	"€ 85,600+€ 1,800-€ 52,283.33"	
						€ 35,116.67	
					ROI (year)	"€ 114,333.33 / € 35,116.67"	
						3.26	

Figure 4: Simulation of cost effects

On the other hand, the overall transaction cost must include the ICT system investment. The calculation of the balance between personnel salary and delivery cost and ICT system investment is shown in figure 4. The left part shows the cost of ICT "Software (SW) + Hardware (HW)" in total and annually. The northwest subsidiary accounts for 1/6 of the number of transactions of the company and as a consequence is assigned 1/6 of the total company wide investment cost. Note that the other subsidiaries benefit from the systems, but those are not made explicit in the calculation. The two systems selected for on-site related and administration based functions are anonymized for confidentiality reasons. The figures are based on accounting results. The right part of the figure shows the values of personnel gross salary per year and postal cost per year that have been estimated by SMEs. As the change from S02 to S09 took Ballast Nedam about 8 years, we suppose the reduction gain proceeds proportional during this period and take the average of the reduction in cost for calculating the yearly balance. The result is positive around 35 thousand euro annually, which expect to see the return of investment (ROI) after about 4 years.

5.2 Operational Procurement Cycle Time

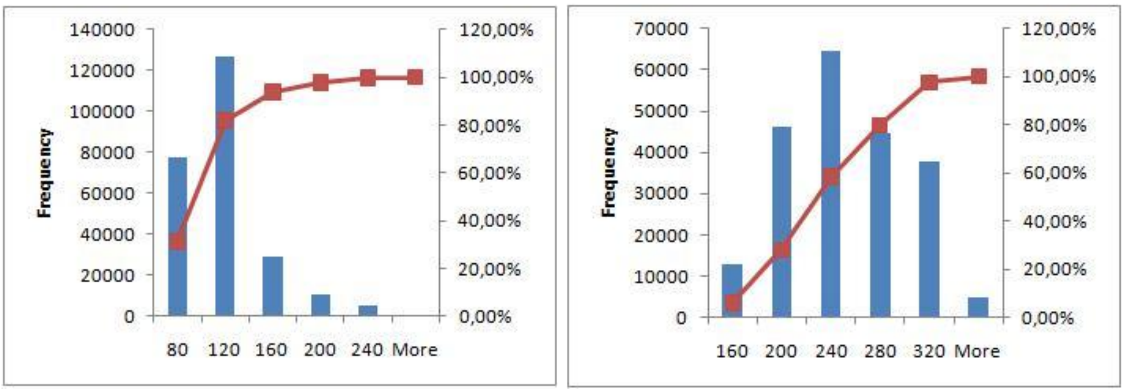

Figure 5: Procurement cycle time measurement (horizontal: cycle time; vertical: frequency; red line: cumulative value)

In the simulation we also measured the cycle time. The histogram for S09 is shown on the left side of figure 5 and the one for S02 is on the right side. The average cycle time of 210622 simulated transactions in 20 runs of S02 is 231.95 (hour, see the horizontal axis). The 249502 transactions in S09 find their cycle time is fluctuating around 98.41 (hour). The majority of transactions (79.89% - 28.05% = 61.84%) in S02 have a completion time between 28 calendar days (120 working hours) and 49 calendar days (280 working hours), while almost 81.97% transactions in S09 are done within 28 calendar days (120 working hours). The improvement in cycle time reduction is obvious and proportional to the maturity grow.

5.3 Information Quality

The information quality is measured by the waiting time in the queues in the simulation. The waiting time represents the period during which information about the transactions is only available locally with limited accessibility and traceability. The shorter the waiting time, the better the information of the transactions is shared, communicated and controlled.

	S02	S09
on-site Q	0.3	0
on-site batch Q	18.94	15.89
on-site dispatch Q	8.09	0
1st control Q	0.17	0.14
1st batch Q	19.43	15.42
1st dispatch Q	7.97	0
2nd control Q	1.24	1.14
2nd batch Q	8.81	8.94
2nd dispatch Q	0.08	0
preprocess Q	3.24	4.19
regi. invoice Q	1.05	0
legi. check Q	0	10.82
match invoice Q	0.67	0.02
r / i match Q	19.99	0
mismatch Q	1.12	0
external Q	0	0
internal Q	18.95	0
admi. dispatch Q	8.06	0
release Q	2.29	0.18
ready for pay Q	0	0

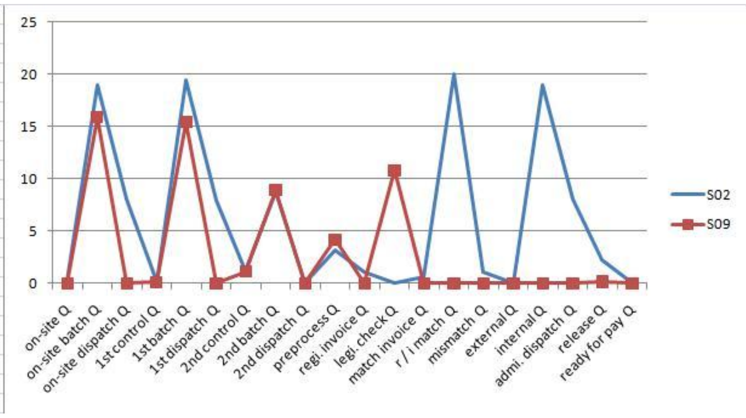

Figure 6: Simulation Procure-to-Pay process

Figure 6 illustrates the information waiting time of S02 and S09. Waiting time is decreasing in almost all the processing steps and in S09 we especially observe minimal delays before central administration functions. The legitimate check queue however becomes a bottleneck because of more required receipt registration details and stricter EU working regulations, as also mentioned in Section 5.1. Moreover, the waiting time is slightly longer in “2nd patch Q” and “preprocess Q”. The sum of the waiting times in S02 is 120.4 (hour) and 56.74 (hour) in S09 which is less than half of that in S02. This again brings the conclusion that the information quality with respect to the timeliness has improved along with the maturity growth.

From the above, all three selected performance indicators of operational excellence are positively aligned with the maturity growth. With the maturity grow from level 2 to level 3, the transaction cost is lower, the transaction cycle time is shorter and the information quality is higher.

6 Conclusions

The maturity model for the PBC-industry can be used to assess the level of maturity of a firm’s procurement function, and can be used as a strategy to define the next level. The correlation between the maturity growth and the performance achievement in terms of operational excellence is supported through simulation validation. The maturity growth trend from commercial level to purchasing coordination proved to be a valid assumption. However, the holistic advance from one maturity level to the next is a complex task and with Ballast-Nedam took years to accomplish.

Our research can be extended by simulating more level-transitions of the maturity model. Moreover, the measurable indicators of the maturity model were not all explicitly simulated, and are also not exhaustive: its completeness deserves further validation and review. The simulation scope can be expended to the full cycle of P2P process.

The usefulness of simulation tooling is confirmed in this research. Yet, assumptions and abstractions need to be made during simulation configuration, and therefor are prone to differences from the real world.

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