Horchimodel 2023 - 26th to 28th June 2023 – Universidad de Almería

ZBG

Modeling of the harvesting process as a subsection of an information and controlling system for horticultural production

L. Müller[1*], R. Luer[1], W. Lentz[2]

[1] Centre for Business Management in Horticulture and Applied Research, Stuttgart, Germany

[2] University of Applied Sciences, Dresden, Germany

[*] Presenting author

Contact: Luis Müller
l.mueller@uni-hohenheim.de

Introduction

- *Aim of this study?*
  - Model the apple harvesting process in order to investigate how digital technologies can support business management decision-making
    - Generate blueprint for a partial model of an information and controlling system (ICS)
    - Generate learning effects for the conception of an overall ICS model

- *Why focus on fruit growing?*
  - **Fruit growing dominates** the German horticultural production sector
    - 31 % of German horticultural companies specialised on production are fruit growers (Isaak and Hübner, 2021)

- *Why focus on apple cultivation?*
  - A total of 12,112 German fruit growing farms cultivate a fruit area of 64,077 ha, planted to **85 % with tree fruit** (ibid)
  - Tree fruit cultivation area is clearly **dominated by apples to 2/3** (Statistisches Bundesamt (Destatis), 2022)

- *Why focus on harvesting process?*
  - **Labor costs are the largest cost factor in apple production**, accounting for about **45% of total costs** (Dietiker et al., 2017)
  - Within apple production process, **harvesting ties up the highest share of labor time with approx. 50 %** (ibid)

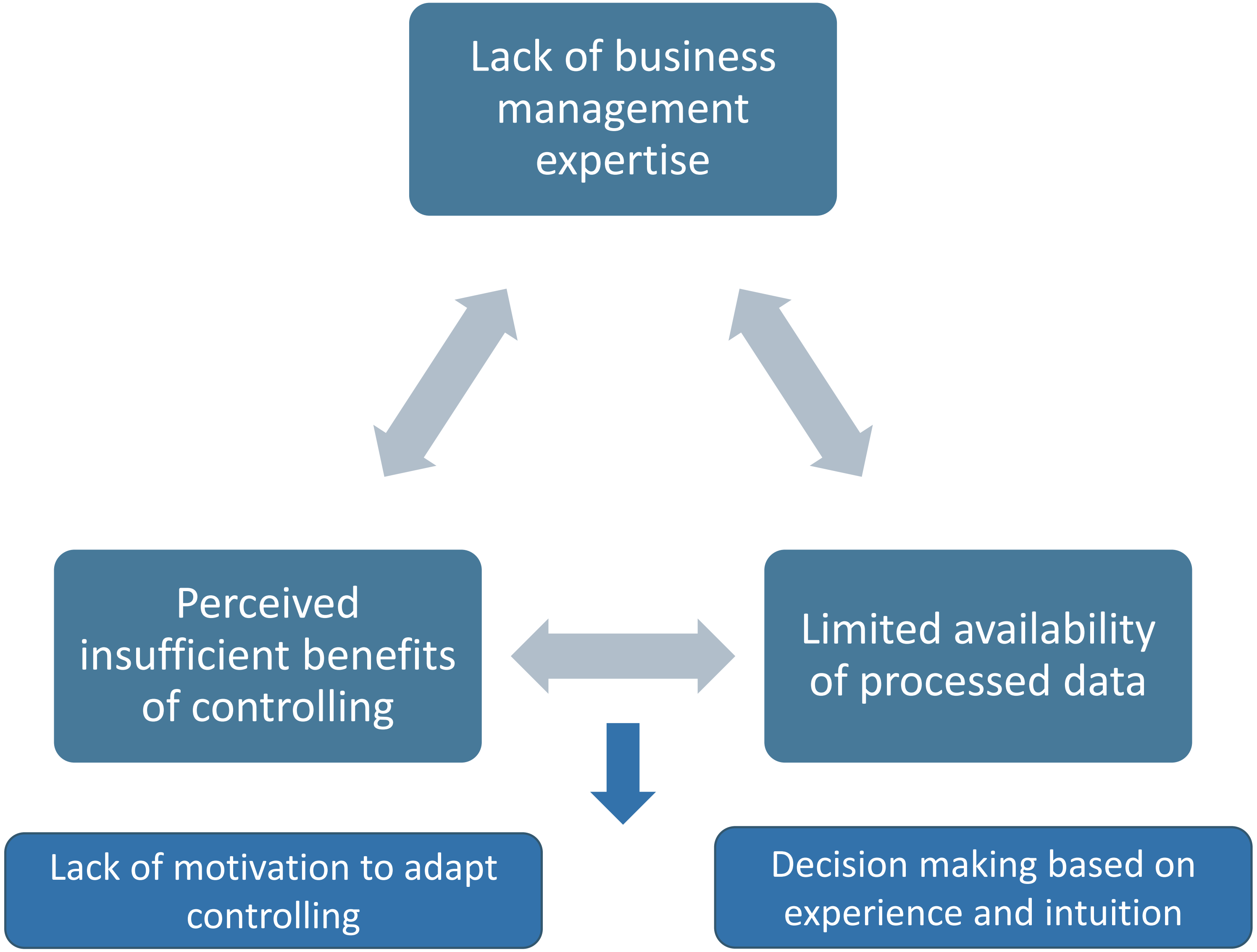

Figure 1: Business management controlling is usually applied rarely and not very intensively in German horticultural companies

Lentz & Dister, 2012
Wolfert et al., 2017

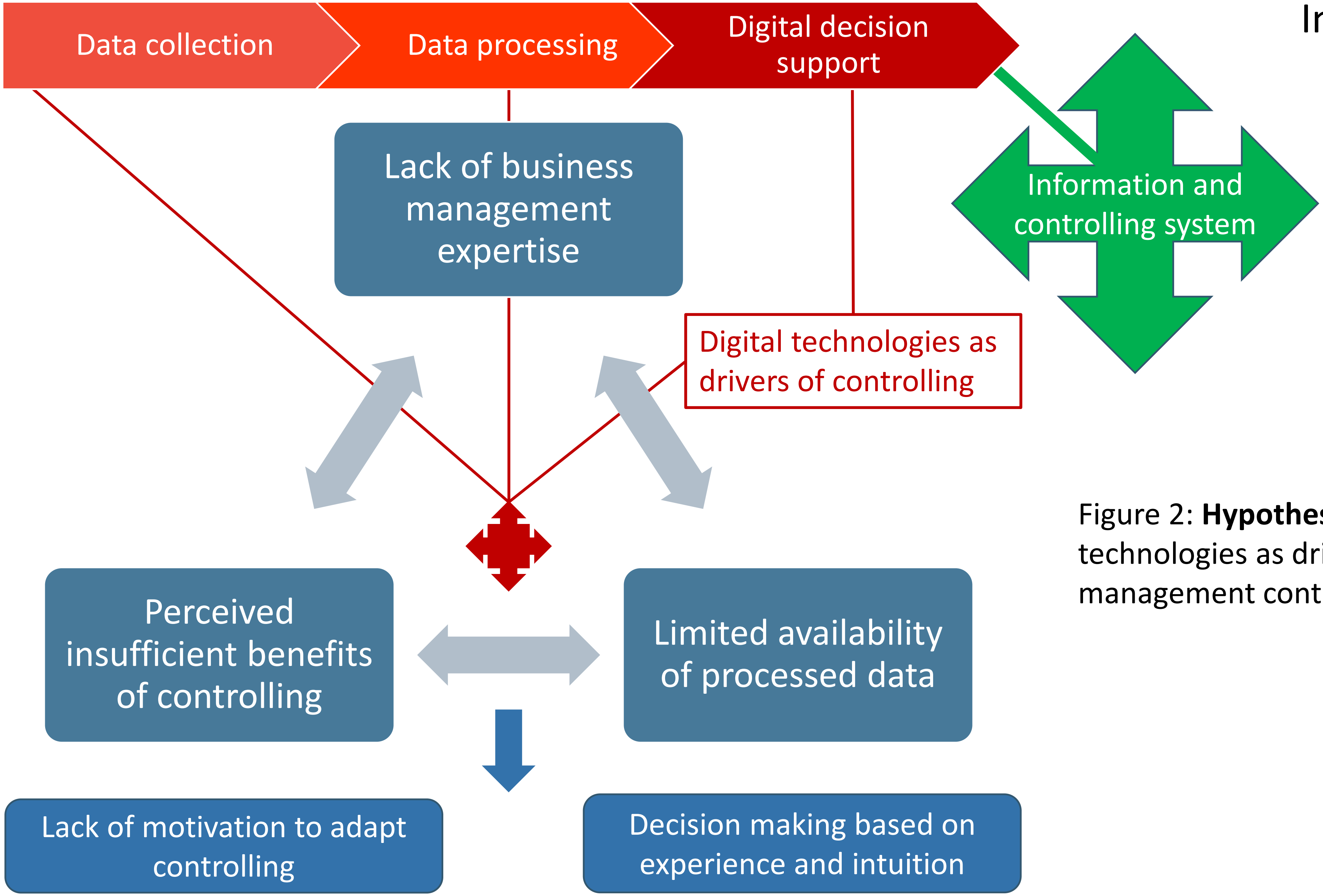

Figure 2: **Hypothesis:** Digital technologies as drivers of business management controlling in horticulture

Giua et al., 2020
Lentz & Dister, 2012
Müller et al., 2022
Wolfert et al., 2017

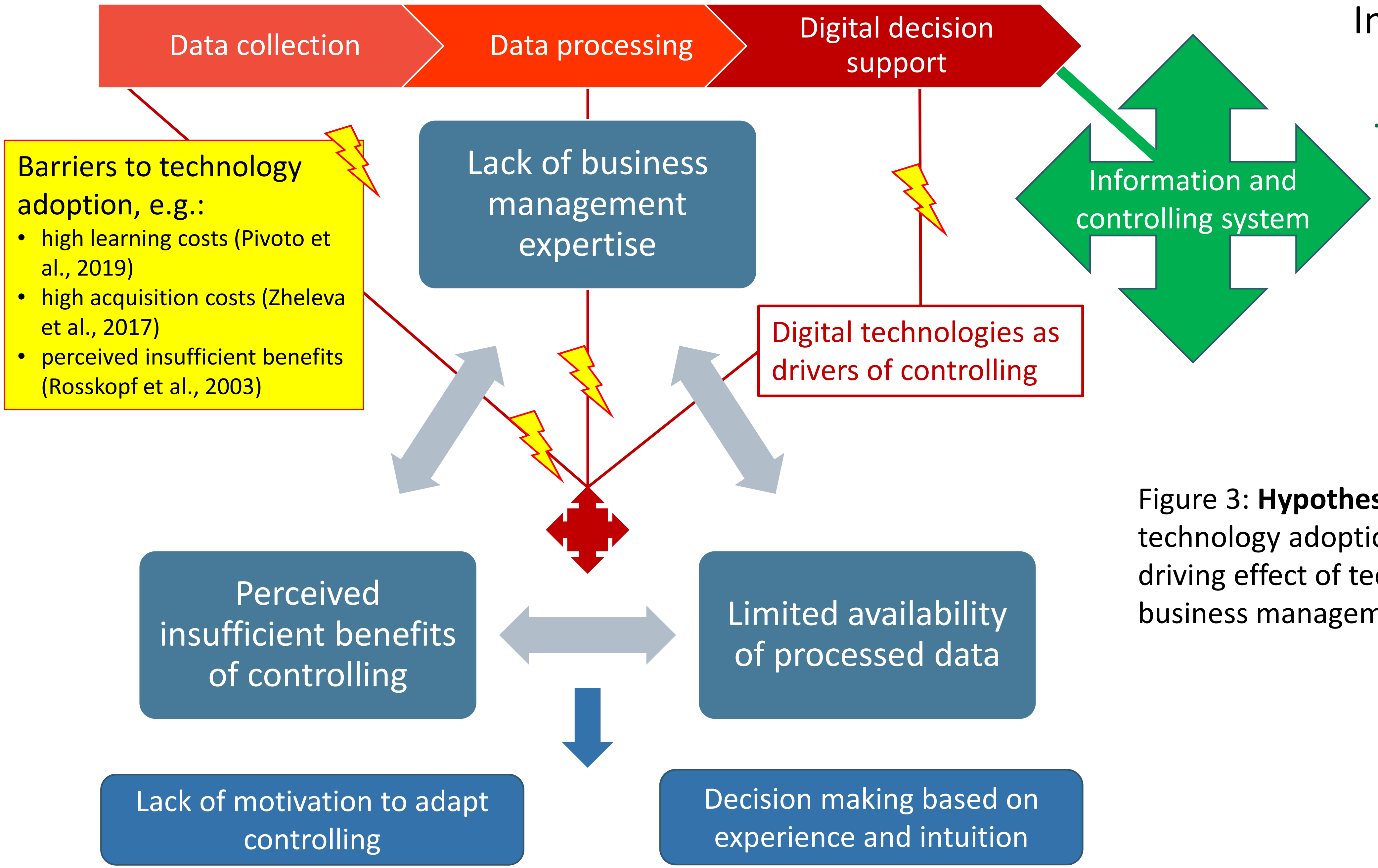

Figure 3: **Hypothesis:** Barriers to technology adoption weaken the driving effect of technologies on business management controlling

Giua et al., 2020
Lentz & Dister, 2012
Müller et al., 2022
Wolfert et al., 2017

Materials and methods

- **Graphical modeling** is suitable for visually structuring and integrating operational process flows and data streams (Engelen and Van Den Brand, 2010)

- *In this study* **graphical modeling should serve as a tool to reduce the complexity** of the real harvesting process in order to be able to… (cf. Lentz, 1998)
  1. … investigate how the **benefits of controlling application** must be designed to outweigh the costs
  2. … to investigate how new **digital technologies can strengthen the benefit side** of controlling
  3. … **uncover potentials of ICS usage** by providing digital business management decision support

- **Graphical specification languages** are used in business informatics and process management across industries (Chinosi and Trombetta, 2012)
  - Standardised means of communication for academia and practitioners (Aguilar-Savén, 2004)
  - Use of predefined symbols (Winter, 2019)

- *In this study* the widespread graphical specification language **BPMN** is used (cf. Wolfert et al., 2010)

Symbol	Name	Description
		Events
Start	Start event	Symbolizes the start of a process. You can add the word 'start' or what the trigger is as a narrative or leave it blank.
End	End event	Shows the end of the process. You can add the word 'end' or the result of the process or leave it blank. There could be more than one end event in a process if there is more than one outcome.
		Participants
Company A, Sales, IT	Pool and swim lanes	A pool is represented by Company A in the illustration example. It should always accompany one or more swim lanes. It will generally be used to represent different boundaries such as company level in a process or swim lanes belonging in different boundaries. A swim lane shows the different participants typically being used to show activities carried out by different departments or roles.
		Activities
	Activity	Represents each activity carried out as part of a process. The naming convention for activities should be short and consist of a verb and an object.
	Collapsed sub-process	If you wish to show that an activity has been broken down further in a separate process diagram, then the plus symbol can be used.

		Connecting objects
	Sequence flow	Shows sequence and helps in navigating through the process and knowing what order to follow.
	Message flow	The sequence flow is not used when showing the relationship between two tasks in different pools. Instead the message flow symbol is used.
		Gateways
	XOR gateway	Represents a decision or more than one option that applies before proceeding to the next task. A question is often asked in conjunction with this symbol being used, and it will have a minimum of two sequence flows going out of it with the different options possible.
		Data
	Data store with association symbol	This can be used to show which tasks use a system or have data stored centrally. The association symbol represented by the dotted line attaches to the relevant tasks. The data store can be named to show the system that the stakeholders are familiar with.
	Data object	This can be used to show which tasks can be associated with different types of documentation. It could be a report, form, guide etc. The association symbol represented by the dotted line attaches to the relevant tasks. The data object can be named with the documentation that the stakeholders are familiar with.

Figure 4: BPMN symbols (Winter, 2019)

Results and discussion

- In order to reduce the complexity of reality, the first step in modeling an ICS is to **break reality of operations down into individual parts** (cf. Lentz, 1998)
- Harvesting process was divided into 3 sub-processes (cf. Büchele, 2018):
  1. Determination of harvesting time
  2. Harvesting
  3. Storage

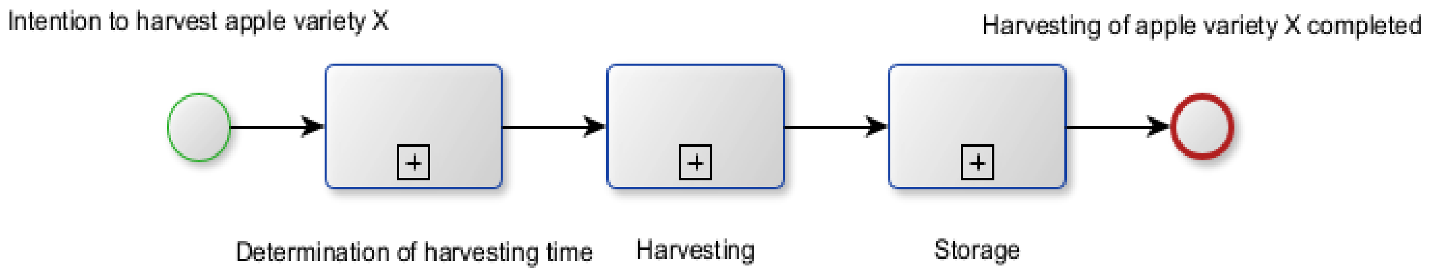

Figure 5: BPMN model of the overall harvesting process

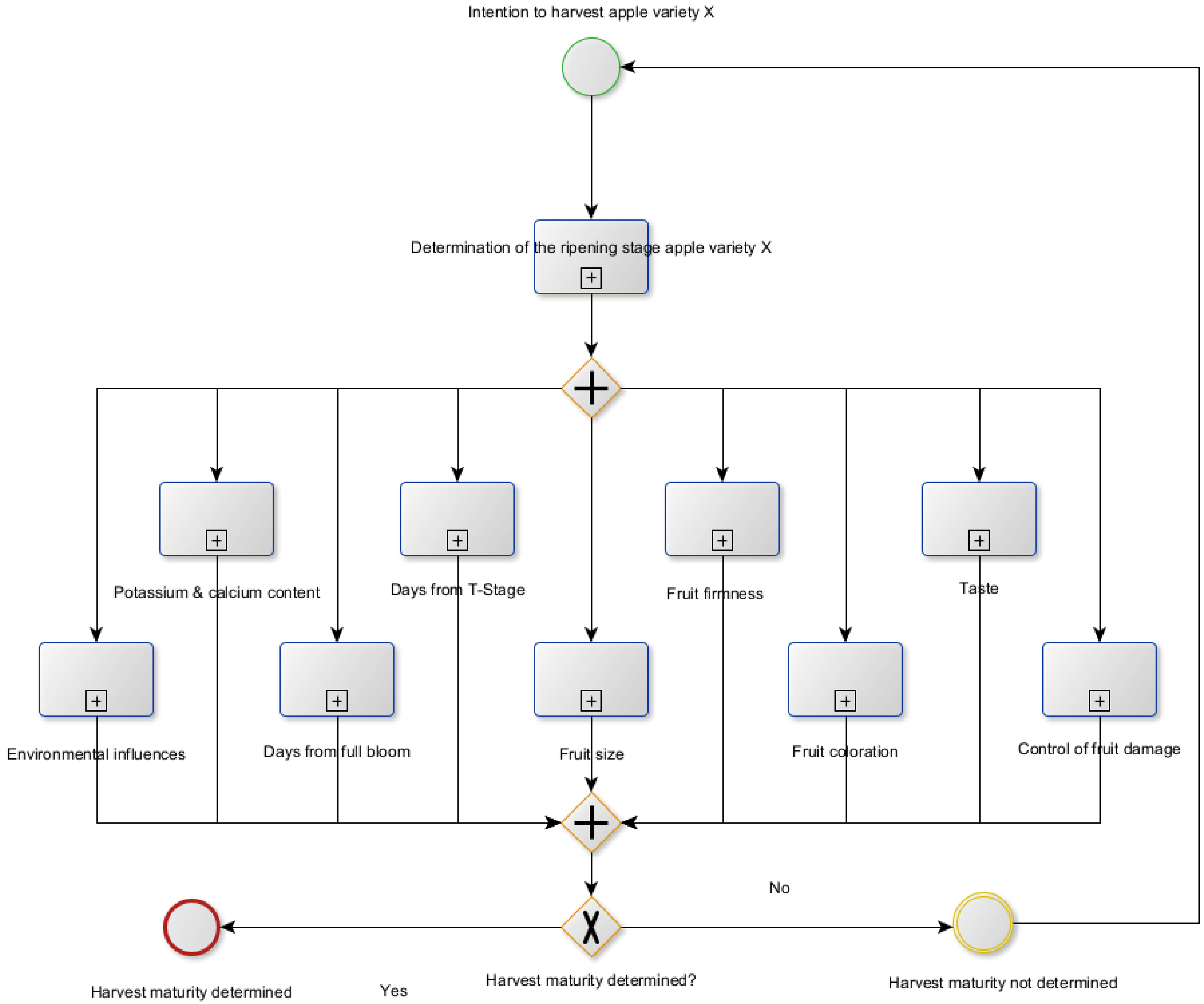

Figure 6: BPMN sub-model for determining harvesting time **(Step 1)**

Creating BPMN sub-model for determining harvesting time in 3 steps…

ICS sub-model for the determination of optimal harvesting time supports the decision which variety to harvest and when:

- Test results of various ripening indicators can be digitally processed and aggregated, increasing measurement accuracy (Büchele, 2018)
- If harvest maturity is determined transition to the harvesting sub-process takes place
- If harvest maturity cannot be determined ripening tests are continued

Results and discussion

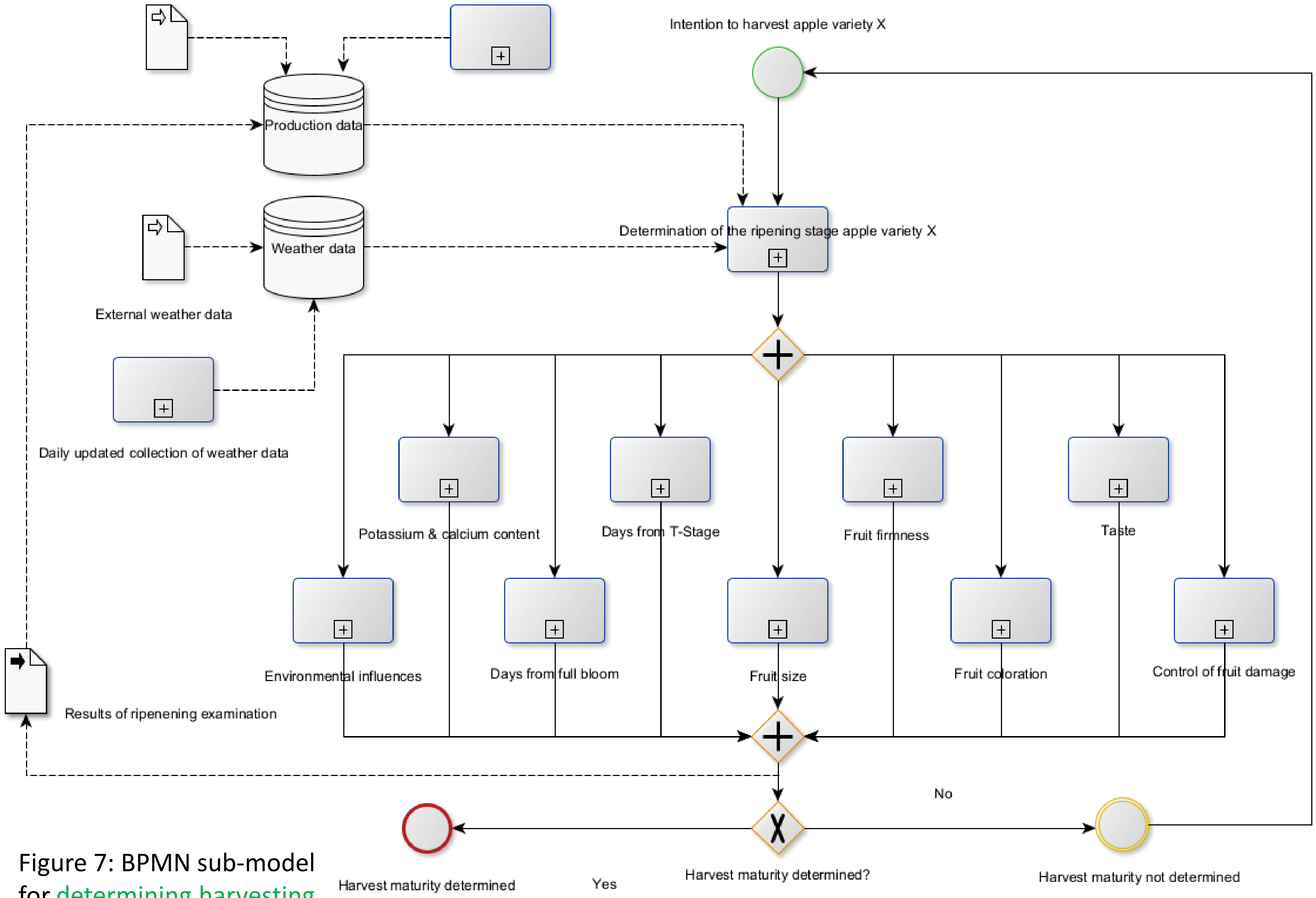

Figure 7: BPMN sub-model for determining harvesting time **(Step 2)**

During the entire production process and finally at the time of concrete intention to harvest, forecasts of harvesting time based on **current and historical production data and external data can be evaluated via an ICS:**

+ Add **production data from the current season**
  - Number of past days from full bloom
  - Number of days from T-stage
  - Data from crop protection documentation (e.g. prescribed waiting period after application of crop protection signals earliest possible harvest time)

+ Add **historical production data**

+ Add **external data** (e.g. harvest recommendation of consulting institutions, weather data)

+ Add **effect of environmental factors** (e.g. precipitation, temperature, hail events)

Results and discussion

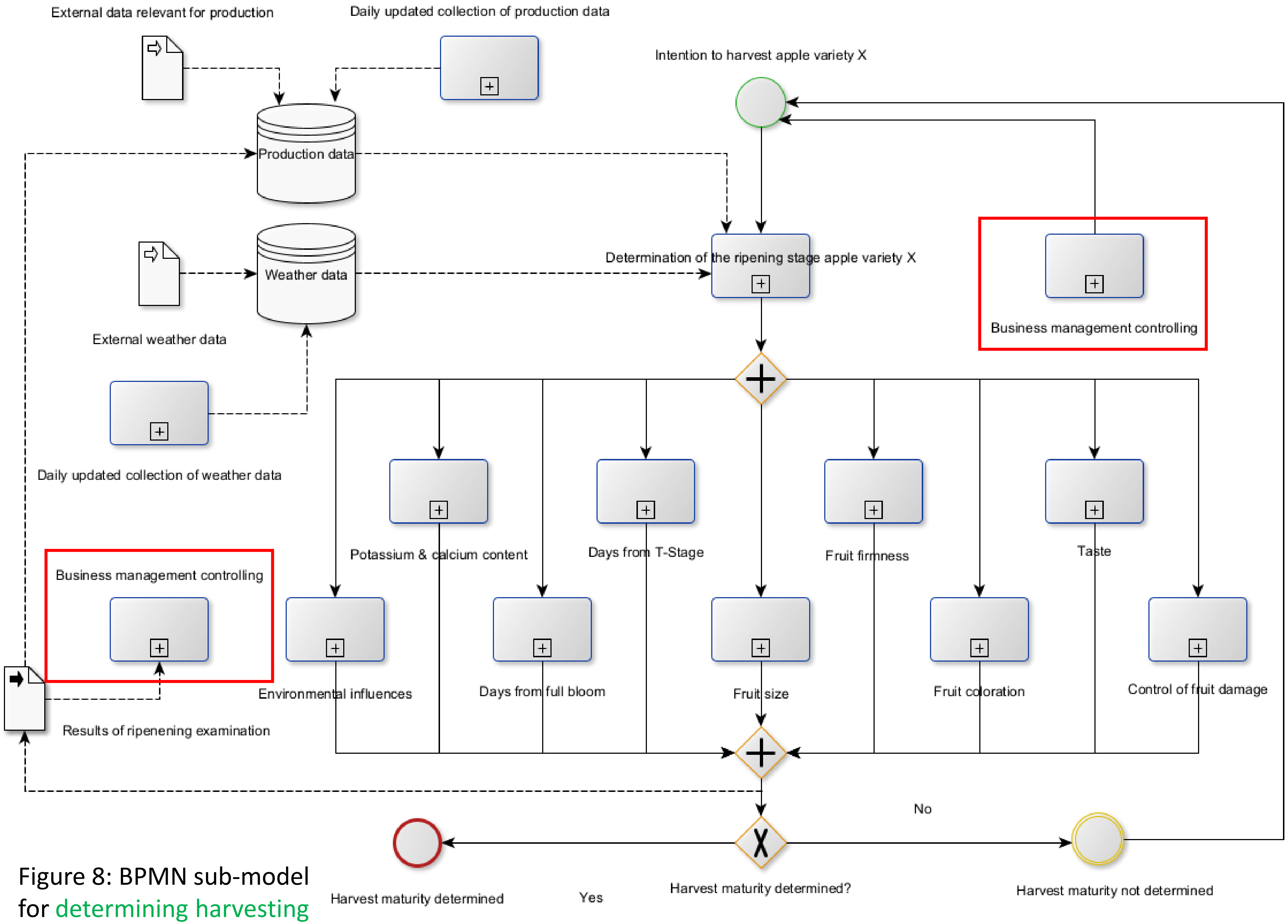

Figure 8: BPMN sub-model for determining harvesting time **(Step 3)**

Interaction with sub-process of business management controlling:

- E.g.: Efficient scheduling of harvest workers, harvesting equipment and technology several months before harvest maturity and during harvesting

Fruit physiological estimation models need to be integrated into ICS to support business management decisions:

- E.g.: Fruit related variables enrich the forecast equation of the **need for harvest workers and equipment**
  - Variety specific harvest times, quantities and qualities
  - Environmental influences
- E.g.: **Planning of downstream sub-processes**
  - Guarantee sufficient variety specific storage capacity for expected harvest date
  - Decision-making basis for communication and negotiation with downstream elements of the value chain

Results and discussion

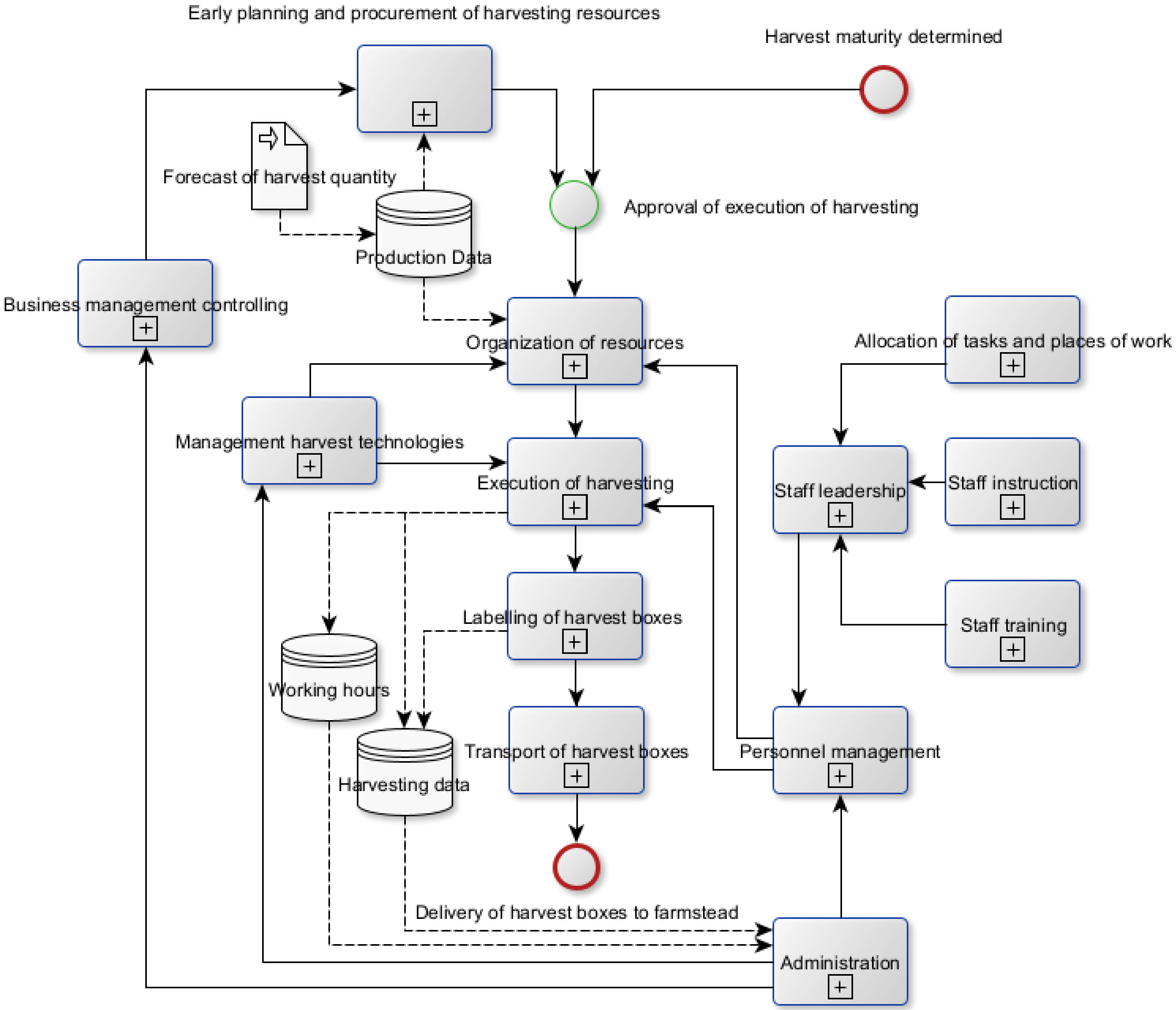

Figure 9: BPMN sub-model for harvesting

Interfaces to upstream, downstream and parallel sub-processes, e.g. **Personnel management**:

- **Staff leadership**, e.g.:
  - Allocation of tasks and places of work
  - Regular instructions und regular training
- **Administration**, e.g.:
  - Arrival & departure, accommodation, insurance and payroll accounting

Data management:

- **Forecast of harvest quantity** needed for organization of resources
  - Number of harvest workers with different skill levels
  - Amount of harvesting equipment and technology

- Recording of **working hours** is central to…
  - comply with payroll accounting and the legally required documentation
  - → generate a database for business management evaluations, e.g. optimization of labour productivity

- Production data recording **level of detail**:
  - Harvest date, field, variety, harvest quantity, quality indicators such as fruit size and weight
  - → Identify the causes of quality deficiencies
  - → Control and optimize crop management

- **Sub-process of labelling harvest boxes**
  - All fruit-related data can be accessed for consecutive sub-processes via (QR) codes on harvest boxes (cf. Yang et al., 2018)

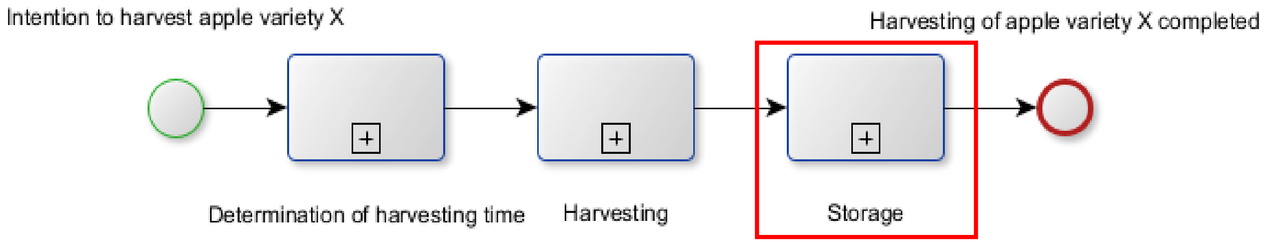

Figure 10: BPMN model of the overall harvesting process focussing storage

Overall harvesting process ends with the completion of the **sub-process of storage**

- Add data to the already collected data for each harvest box:
  - Selected storage room and its settings
  - Individual position of the harvest box inside of the storage room
- Suitable storage location and expected storage period =
  - Variety-specific fruit physiological storage characteristics (Büchele, 2018)

    \+
  - Expected time of optimal variety-specific market demand
- Digital twins of the storage rooms can be created within the ICS (cf. Verdouw et al., 2021)
  - Suitable tool to check the stock and to react quickly to market demands

Production process is continued by entering the sub-process of sorting and distribution…

Conclusion

- Clear necessity of developing holistic ICS approaches in order to be able to take into account the numerous interactions of sub-processes that affect decision-making processes
- High *theoretical* potential for benefitial ICS usage regarding the collection and transformation of data into decision-relevant information during the harvesting process
- Graphical modeling of the harvesting process has proven to be a helpful methodical tool to…
  - structure complex real processes of operations at model level
  - show at which process stages digital technologies can support business management decision-making
  - provide a basis for discussion for further development of ICS in horticulture for both science and practice using BPMN
- Future research
  - Empirical validation
  - Variation of abstraction level of modeling
  - Transfer of findings into the context of the entire production process and its accompanying business management controlling

Literature cited

Aguilar-Savén, R.S. (2004). Business process modelling: Review and framework. Int. J. Prod. Econ. 90, 129–149. https://doi.org/10.1016/S0925-5273(03)00102-6.

Büchele, M., ed. (2018). Lucas’ Anleitung zum Obstbau, 33rd edn (Ulmer), pp.524.

Chinosi, M., and Trombetta, A. (2012). BPMN: An introduction to the standard. Comput. Stand. Interfaces 34, 124–134. https://doi.org/10.1016/J.CSI.2011.06.002.

Dietiker, D., Hanhart, J., and Bravin, E. (2017). Arbeiten im Obstbau. Schweizer Zeitschrift Für Obst- und Weinbau 11, 9–13.

Engelen, L., and Van Den Brand, M. (2010). Integrating textual and graphical modelling languages. Electron. Notes Theor. Comput. Sci. 253, 105-120. https://doi.org/10.1016/j.entcs.2010.08.035.

Giua, C., Materia, V.C., and Camanzi, L. (2021). Management information system adoption at the farm level: Evidence from the literature. Br. Food J. 123, 884-909. https://doi.org/10.1108/BFJ-05-2020-0420.

Isaak, M., and Hübner, S. (2021). Der Gartenbau in Deutschland - Auswertung des Gartenbaumoduls der Agrarstrukturerhebung 2016 (Bundesministerium für Ernährung und Landwirtschaft), pp.76.

Lentz, W. (1998). Model applications in horticulture: A review. Sci. Hortic. 74, 151–174. https://doi.org/10.1016/S0304-4238(98)00085-5.

Lentz, W., and Dister, M. (2012). The adoption of control instruments for farm management by horticulture farms in Germany. Acta Hortic. 930, 155–160. https://doi.org/10.17660/ActaHortic.2012.930.20.

López, O.L., and Hiebl, M.R.W. (2015). Management accounting in small and medium-sized enterprises: Current knowledge and avenues for further research. J. Manag. Account. Res. 27, 81–119. https://doi.org/10.2308/jmar-50915.

Michels, M., Fecke, W., Feil, J.H., Musshoff, O., Pigisch, J., and Krone, S. (2020). Smartphone adoption and use in agriculture: Empirical evidence from Germany. Precis. Agric. 21, 403–425. https://doi.org/10.1007/s11119-019-09675-5.

Literature cited

Müller, L., Luer, R., Krause, H., and Lentz, W. (2022). Digitale Transformation als Treiber von Controlling im Gartenbau - Ein konzeptioneller Ansatz. Lecture Notes in Informatics (LNI), Proc. of the 42nd conference of the Gesellschaft für Informatik (GIL), Tänikon, 201-206.

Ndemewah, S.R., Menges, K., and Hiebl, M.R.W. (2019). Management accounting research on farms: What is known and what needs knowing? J. Account. Organ. Chang. 15, 58–86. https://doi.org/10.1108/JAOC-05-2018-0044.

Pivoto, D., Barham, B., Waquil, P.D., Foguesatto, C.R., Corte, V.F.D., Zhang, D., and Talamini, E. (2019). Factors influencing the adoption of smart farming by Brazilian grain farmers. Int. Food Agribus. Manag. Rev. 22, 571–588. https://doi.org/10.22434/IFAMR2018.0086.

Rosskopf, K. and Wagner, P. (2003). Requirements for agricultural software and reasons for adoption constraints - Results of empirical studies. European Federation for Information Technologies in Agriculture (EFITA), Debrecen, 651-657.

Statistisches Bundesamt (Destatis) (2022). Flächen und Erntemengen im Marktobstbau.

Verdouw, C., Tekinerdogan, B., Beulens, A., and Wolfert, S. (2021). Digital twins in smart farming. Agric. Syst. 189, 103046. https://doi.org/10.1016/j.agsy.2020.103046.

Wolfert, J., Verdouw, C.N., Verloop, C.M., and Beulens, A.J.M. (2010). Organizing information integration in agri-food - A method based on a service-oriented architecture and living lab approach. Comput. Electron. Agric. 70, 389–405. https://doi.org/10.1016/j.compag.2009.07.015.

Winter, H. (2019). The Business Analysis Handbook: Techniques and Questions to Deliver Better Business Outcomes. United Kingdom: Kogan Page.

Yang, F., Wang, K., Han, Y., and Qiao, Z. (2018). A cloud-based digital farm management system for vegetable production process management and quality traceability. Sustain. 10, 4007. https://doi.org/10.3390/SU10114007.

Zheleva, M., Bogdanov, P., Zois, D.S., Xiong, W., Chandra, R., and Kimball, M. (2017). Smallholder agriculture in the information age: Limits and opportunities. LIMITS '17 Proc., Santa Barbara, 59–70. https://doi.org/10.1145/3080556.3080563.

Thank you for your attention!

Luis Müller, M.Sc.
l.mueller@uni-hohenheim.de

Centre for Business Management in Horticulture and Applied Research, University of Hohenheim, Stuttgart