APPENDIX – Assessing Smart Manufacturing by Combining IT Systems and Enabling Technologies in a Fuzzy Cognitive Maturity Model

Appendix

1. Experts data

Information of the 19 experts selected during the *Step 3* is reported in Table 1. For each expert, the table reports the role, the sector, its expertise, the background in the case of academics, and the type of user and company size in the case of an expert coming from the industry.

Table 1. Information of the experts

Expert ID	Role	Primary Sector	IT System	Background	
E1	Researcher	Academia	CAD/CAM/PLM, CRM, ERP/SCM, WMS/TMS, MES	Industrial	
E2	Researcher	Academia	CAD/CAM/PLM, CRM, ERP/SCM, WMS/TMS, MES	Industrial	
E3	Associate Professor	Academia	CAD/CAM/PLM, CRM, ERP/SCM, WMS/TMS, MES	Industrial	
E4	Researcher	Academia	CAD/CAM/PLM, CRM, ERP/SCM, WMS/TMS, MES	Information Systems	
E5	Researcher	Academia	CAD/CAM/PLM, CRM, ERP/SCM, WMS/TMS, MES	Information Systems	
E6	Full Professor	Academia	CAD/CAM/PLM, CRM, ERP/SCM, WMS/TMS, MES	Information Systems	
E7	Researcher	Academia	CAD/CAM/PLM, CRM, ERP/SCM, WMS/TMS, MES	Information Systems	
				Developer / User	**Company Size**
E8	Product Designer	Mechatronics	CAD/CAM/PLM	User	Large
E9	Project Manager	Manufacturing	CAD/CAM/PLM	User	Large
E10	IT Solution Advisor	Information Technology	CRM, ERP/SCM	Developer	Large
E11	IT Senior Consultant	Information Technology	ERP/SCM	Developer	Large
E12	IT Senior Consultant	Information Technology	ERP/SCM	Developer	Medium
E13	IT Senior Consultant	Information Technology	ERP/SCM	Developer	Large
E14	MES engineer	Pharmaceutical	MES	User	Large
E15	Director of Manufacturing	Manufacturing	MES	User	Large
E16	IT Demand Manager	Precision Engineering	WMS/TMS	User	Large
E17	Project Manager	Logistics	WMS/TMS, MES	Developer	Medium
E18	Prototypes, Tests Experiences Manager	Mechatronics	CAD/CAM/PLM	User	Large
E19	Electronics RD Manager	Mechatronics	CAD/CAM/PLM	User	Large

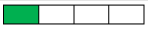
2. Example Expert

Table 2 and Table 3 reports the data resulting from the interview with expert E9 for the CAD/CAM/PLM IT system. Particularly, Table 3 indicates the causal relationships among the technologies within the IT system. The causal relationship is indicated as an array of four elements filled depending on the specific linguistic term, i.e., the array filled with two green elements corresponds to "medium" and the array filled with one green element corresponds to "low".

Table 2. Accepted technologies for E9

Technologies	**Accept**	**Expert notes**
IIoT	✓	Real-time notifications in the automatic generation of spare parts
Cloud	✓	The system is now often offered in a cloud solution
AI	✓	Product management (e.g., predictive maintenance)
CS	✗	
Robot	✗	
AR/VR	✗	
DT	✓	In the PLM in the design and engineering phase, DT are used
DM	✗	

Table 3. Relationships between technologies for E9

Relationships between technologies	IIoT	Cloud	AI	DT
IIoT	–			
Cloud	Neutral	–	Neutral	Neutral
AI	Neutral		–	
DT	Neutral		Neutral	–

3. Adjacency matrices

Table 4- 8 reports the final causal relationships resulting from the interviews.

Table 4. CAD, CAM, PLM adjacency matrix

	IIoT	Cloud	AI	CS	AR/VR	DT	DM
IIoT	0	0.20	0.12	0.12	0	0.16	0.12
Cloud	0	0	0.37	0.45	0.16	0.54	0.41
AI	0	0.25	0	0.20	0.04	0.5	0.29
CS	0	0.33	0.29	0	0.12	0.37	0.37
AR/VR	0	0.12	0.08	0.12	0	0.12	0
DT	0	0.25	0.33	0.29	0.25	0	0.37
DM	0.12	0.20	0.33	0.33	0	0.41	0

Table 5. CRM adjacency matrix

	IIoT	Cloud	AI	CS	AR/VR	DM
IIoT	0	0.25	0.31	0	0.06	0.31
Cloud	0.25	0	0.56	0.43	0.31	0.5
AI	0	0.18	0	0.18	0.25	0.75
CS	0.37	0.65	0.5	0	0.18	0.75
AR/VR	0	0.18	0	0	0	0
DM	0	0.31	0.25	0.43	0.12	0

Table 6. ERP, SCM adjacency matrix

	IIoT	Cloud	AI	CS	Robot	AR/VR	DT	DM
IIoT	0	0.15	0.45	0.2	0.1	0.2	0.15	
Cloud	0.35	0	0.65	0.4	0.2	0.25	0.25	0.5
AI	0.15	0.15	0	0.15	0.1	0.15	0.3	0.2
CS	0.1	0.7	0.4	0	0.2	0.15	0.25	0.5
Robot	0	0.15	0	0	0	0.1	0.05	0
AR/VR	0	0.15	0	0	0.1	0	0.1	0.1
DT	0	0.15	0.1	0.05	0	0.1	0	0.25
DM	0.15	0.4	0.5	0.5	0	0.25	0.1	0

Table 7. WMS, TMS adjacency matrix

	IIoT	Cloud	AI	CS	Robot	AR/VR	DT	DM
IIoT	0	0	0.25	0.16	0.5	0.16	0.5	0.66
Cloud	0.25	0	0.16	0	0.08	0.08	0.16	0.33
AI	0	0	0	0	0.33	0.16	0.25	0.41
CS	0.41	0.25	0.16	0	0.25	0	0.08	0.33
Robot	0.33	0	0.16	0.16	0	0.08	0.16	0.5
AR/VR	0	0	0	0	0.08	0	0.33	0.25
DT	0.25	0	0.16	0.08	0.08	0.25	0	0.41
DM	0	0	0.16	0.33	0	0	0.16	0

Table 8. MES adjacency matrix

	IIoT	Cloud	AI	CS	Robot	AR/VR	DT	DM
IIoT	0	0.18	0.5	0.12	0.37	0.12	0.31	0.56
Cloud	0.18	0	0.5	0.12	0.12	0.25	0.31	0.37
AI	0.18	0.18	0	0.18	0.5	0.25	0.12	0.31
CS	0.68	0.5	0.5	0	0.31	0.31	0.43	0.5
Robot	0.37	0.06	0.5	0.25	0	0	0	0.18
AR/VR	0.18	0.18	0.18	0.18	0.06	0	0.18	0
DT	0.18	0	0	0.25	0.06	0.18	0	0.25
DM	0.25	0.25	0.31	0.25	0	0	0.43	0

References