REF2021

Institution: University of Westminster	
Unit of Assessment: 11 Computer Science and Informatics	
Title of case study: A secure and scalable cloud computing platform to support SMEs and public sector organisations through economic impact and efficiency gains	
Period when the underpinning research was undertaken: 01/07/2008 – 31/07/2020	
Details of staff conducting the underpinning research from the submitting unit:	

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI: (1) 11/2001+ (2) 10/2000 - 07/2017, 08/2018+ (3) 09/2015+ (4) 09/2016+ (5) 09/2001+
(1) Prof Tamas Kiss (2) Dr Gabor Terstyanszky (3) Dr Antonis Michalas (4) Dr Gabriele Pierantoni (5) Mr Huseyin Dagdeviren	(1) Professor (2) Professor, Principal Research Fellow (3) Lecturer, Research Fellow (4) Lecturer (5) Senior Lecturer	

Period when the claimed impact occurred: 01/01/2015 – 31/12/2020	
Is this case study continued from a case study submitted in 2014? ~~Y/~~N	

1. Summary of the impact (indicative maximum 100 words)

The impacts are generated via a set of novel and innovative technologies, called the CloudSME Simulation Platform (CSSP), the CloudiFacturing Platform (CFGP) and MiCADO, which were invented and developed across a string of European projects. Prof Kiss and his team was the lead partner driving the conceptualisation and implementation of CSSP and MiCADO, and they contributed significantly (overall concept and 2 out of 5 platform components) to CFGP.

- CSSP/CFGP has enabled 86 SMEs (small and medium sized enterprises) from over 20 European countries to generate an estimated cumulative turnover increase of 100 million Euros, approximately 550 new products or services, 650 new jobs, and 1,100 new business/commercial partners or customers by the end of 2020.
- CloudSME UG, a for-profit start-up company through which CSSP/CFGP and their MiCADO extension are primarily marketed, reported EUR 222,701 turnover in 2019, with 39,823 annual profit.
- Public sector organisations have also benefitted from the CSSP coupled with MiCADO. The local government of the Aragon region of Spain reported higher satisfaction towards government services, and [text removed for publication] (UK) estimated gains including 100 (10%) new business partners/customers, 212K Euros (7.5%) increase in turnover, 20% more efficient business processes, and 50% reduction in time to market by July 2019.

2. Underpinning research (indicative maximum 500 words)

CSSP/CFGP is a combination of novel and innovative technologies directly brought about by the Centre for Parallel Computing (CPC) team at the University of Westminster between 2005 and 2020, based on the following major research findings.

Science gateways for interoperable grid and cloud infrastructures (**Kiss**, **Terstyanszky**):
CSSP/CFGP originates in **WS-PGRADE/gUSE** [1], an open source **science gateway framework** (an interface for those who want to use grid and cloud infrastructures). WS-PGRADE/gUSE is the outcome of five FP7 European projects between 2008 and 2014 that were either led by, or featured significant contributions from, the CPC team. The main contribution of the CPC was to extend the framework to provide **interoperability for applications, data and workflows,** as evidenced in [1]. WS-PGRADE/gUSE was originally intended for academic users and grid computing platforms. However, with significant contribution from CPC within the [SCI-BUS](SCI-BUS) (Scientific Gateway-based User Support) project, the gateway framework was integrated with the commercial CloudBroker platform so industry applications could be run on a **variety of cloud computing resources**.

Generic cloud-based simulation platform for industry (**Kiss**, **Terstyanszky**, **Michalas**):
The next stage of research, when the above commercial application came to be known as the CSSP [2] [3], was undertaken via the CloudSME (Cloud-based Simulation Platform for Manufacturing and Engineering) project that was led and coordinated by Westminster's CPC (**Kiss**). CSSP was specifically tailored to support **large-scale industry simulations on cloud resources**, especially within the manufacturing / engineering sector. CSSP specifically enables SMEs to use state of the art simulation technology in a cost-efficient way.

To further enhance CSSP, research and development activities were funded by the H2020 CloudiFacturing (Cloudification of Production Engineering for Predictive Digital Manufacturing) project. The outcome of this research is the CloudiFacturing Platform (CFGP); a new and enhanced version of CSSP. CFGP supports the **dynamic combination of workflows** and features a newly developed service model for SMEs in the form of a dedicated **Digital Marketplace**. The CPC team was responsible for the development of its executable artefact (workflow and application) repository (**Terstyanszky**) and security framework (**Michalas**). Additionally, development of the workflow execution and data transfer components were strongly influenced by the work of the CPC from past EU projects (SHIWA (2010-2012), ER-FLOW (2012-2014) (**Kiss**, **Terstyanszky**).

Innovative cloud-based business models (**Kiss**, **Dagdeviren**):
In order to further facilitate the industrial take-up of CSSP, further research was carried out in the area of **cloud-based business models,** with particular focus on the application of such business models for large scale simulations in manufacturing [4]. These business models enable software vendors to efficiently sell simulation services to manufacturing end-users using a cloud-based service provision model.

Application-level cloud orchestration (**Kiss**, **Terstyanszky**, **Michalas**, **Pierantoni**):
As part of the H2020 European COLA (Cloud Orchestration at the Level of Application) project, led by CPC (**Kiss**), the CSSP has been further extended with a **secure cloud orchestration framework** called MiCADO [5]. MiCADO is an external service to the CSSP and allows for various services connected within the cloud to utilise the optimal amount of resources, thus boosting the efficiency of cloud-based applications. The framework enables companies to run applications on various heterogeneous clouds and to define highly flexible scaling and security policies that govern the execution of their applications [6].

3. References to the research (indicative maximum of six references)
[1] Peter Kacsuk, **Tamas Kiss**, Gergely Sipos: Solving the Grid Interoperability Problem by P-GRADE Portal at Workflow Level, *Future Generation Computing Systems*, Volume 24, Issue 7, July 2008, pp 744-751
[2] Simon JE Taylor, **Tamas Kiss**, Anastasia Anagnostou, **Gabor Terstyanszky**, Peter Kacsuk, Joris Costes, Nicola Fantini: The CloudSME Simulation Platform and its Applications: A Generic Multi-cloud Platform for Developing and Executing Commercial Cloud-based Simulations, in *Future Generation Computing Systems,* Volume 88, November 2018, pp 524- 539
[3] Simon JE Taylor, Anastasia Anagnostou, **Tamas Kiss**, **Gabor Terstyanszky**, Peter Kacsuk, Nicola Fantini, Djamel Lakehal, Joris Costes: Enabling Cloud-based Computational Fluid Dynamics with a Platform as a Service Solution, in *IEEE Transactions on Industrial Informatics*, Volume 15, Issue 1, January 2019, pp 85-94
[4] **Tamas Kiss, Huseyin Dagdeviren,** Simon J E Taylor, Anatasia Anagnostou, Nicola Fantini, Business Models for Cloud Computing: Experiences from Developing Modeling & Simulation as a Service Applications in *Industry, Proceedings of the 2015 Winter Simulation Conference*, L. Yilmaz, W. K. V. Chan, I. Moon, T. M. K. Roeder, C. Macal, and M. D. Rossetti, eds., 2015, pp 2656-2667, ISBN: 978-1-4673-9741-4, IEEE Press.
[5] **Tamas Kiss**, Peter Kacsuk, Jozsef Kovacs, Botond Rakoczi, Akos Hajnal, Attila Farkas, Gregoire Gesmier, **Gabor Terstyanszky**: MiCADO–Microservice-based Cloud Application-level Dynamic Orchestrator, in *Future Generation Computing Systems,* Volume 95, May 2019, pp 937 – 946
[6] **Gabriele Pierantoni**, **Tamas Kiss**, **Gabor Terstyanszky**, James Deslauriers, Gregoire Gesmier, Hai-Van Dang: Describing and Processing Topology and Quality of Service Parameters of Applications in the Cloud, in *Journal of Grid Computing,* Volume 18, June 2020. pp 761–778
Grants awarded:
SCI-BUS (EU FP7), 01 October 2011 - 30 September 2014, All: £3,125,000, CPC: £280,000 [1]
CloudSME (EU FP7), 01 July 2013 - 31 March 2016, All: £3,750,000; CPC: £540,000 [2] [3] [4]
COLA (EU H2020), 01 January 2017 - 30 June 2019, All: £3,000,000; CPC: £726,000 [2] [5] [6]

CloudiFacturing (EU H2020), 1 October 2017 - 31 March 2021 All: £7,250,000; CPC: £620,000 [2]
ASCLEPIOS (EU H2020), 1 Dec. 2018 - 30 Nov. 2021 All: £4,040,000; CPC: £470,000 [6]
DIGITbrain (EU H2020), 1 July 2020 - 31 December 2023, All: £7,600,000; CPC: £360,000 [5] [6]
CO-VERSATILE (EU H2020), 1 Nov. 2020 - 31 Oct. 2022 All: £4,900,000; CPC: £300,000 [5] [6]

4. Details of the impact (indicative maximum 750 words)

Simulation and optimisation can significantly improve the competitive position of companies and public sector organisations by reducing their costs as a result of more efficient development, production, procurement, logistics or financial processes. However, the take up of simulation / optimisation software by SMEs and the public sector has been low due to barriers of entry such as hardware prices, licensing costs and required technical expertise. With Prof Kiss and his team leading the research and technical development efforts, CSSP/CFGP, combined with MiCADO, proved efficient to **overcome these barriers** and has since generated significant **economic impact and further efficiency gains** for a large number of organisations in Europe.

Impact on SME clients:
By April 2020, **86 SMEs from over 20 European countries** – manufacturing, engineering and technology companies that participated in the CloudSME, COLA and CloudiFacturing projects as beneficiaries or as Third Parties – reported the following estimated economic impact as a direct result of applying either CSSP or CFGP, in tandem with the MiCADO secure autoscaling framework: a cumulative yearly **turnover increase of over 100 million Euros**, the development of over **550 new / enhanced products or services**, contribution to the creation of **650 new jobs**, and the establishment of **1,100 new business/commercial partners or customers**. This economic impact occurred between 2015 and 2020.

These figures are evidenced in the official project reports/deliverables of the CloudSME, COLA, and CloudiFacturing projects that were provided by executives of the participating companies and approved by the European Commission [a, b, c, d]. This approval affirms the credibility and accuracy of the forecasted economic growth by these 86 companies, as attributable to the CPC's research across these three projects. Figures 1, 2 and 3, on pages 4 and 5 below, summarise the above detailed numbers.

Figure 1 summarises the impact of CSSP on 24 companies within the CloudSME project. Figure 2 provides details of the economic impact of utilising MiCADO with the CSSP by 10 companies within COLA. Figure 3 encompasses the impact of the CFGP on 52 companies that were supported in three waves during the CloudiFacturing project (please note that due to the very large number of companies, only cumulative figures are shown here, details are available in [c,d]).

Additionally, these companies reported **improved business processes**, **improved business practices**, **reduction in time to market**, and **improved customer satisfaction**. Two online videos made by Hobsons Brewery [e], a UK-based craft-brewer, and Podoactiva [f], a Spanish manufacturer of tailored foot insoles, provide narrative accounts detailing these impacts.

Beyond the directly reported figures, it is also important to note that **significant economic impact has been generated for the clients of the directly supported / involved companies**, across a wide range of sectors. For instance, the Managing Director of Saker Solutions, which provides "*a range of 3D simulation and modelling services*" to clients within industrial and commercial sectors and is one of the 86 SMEs mentioned above, states the company itself benefitted from "*an increase in turnover of at least £200k pa since 2014 which has allowed us to employ additional staff*" and also estimates that "*over the last 7 years we have generated some £2 to £3 million of benefit*" for their clients: "*Primarily this benefit would be in the Nuclear sector but savings will have also been generated within Manufacturing, Defence and Retail*" [g]. He concludes that: "*Overall, Prof Kiss has had a major impact on our company*" [g].

Impact on CloudSME UG; the commercial service provider:
CSSP/CFGP is primarily marketed and provided by **CloudSME UG**, a for-profit start-up company that also offers related expertise and consultancy to clients. Established in January 2016, the company's profits have substantially grown through its continued collaboration with the Westminster researchers, as the Managing Partner confirms: "*the product and service portfolio offered by CloudSME UG is based and heavily relying on novel and innovative technologies that*

were invented, designed and implemented by Prof. Kiss and the Centre for Parallel Computing research team" [h]. The technological and research contribution of the CPC in the creation of CSSP was also acknowledged via the appointment of Kiss as the Chair of the Scientific Advisory Board of the company. In this unpaid role, Kiss acts as their main scientific and technology consultant and helps to define their current and future direction. The company made steady growth on the market between 2016 and 2020 by securing and successfully delivering its commercial contracts. As a result of utilising the CSSP, CloudSME reported **222,701 Euros turnover in 2019**, with **39,823 Euros annual profit** [h].

As CloudSME's CEO states, since July 2019, "*the product portfolio of my company* [CloudSME] *has been further extended and we are now offering fully managed professional cloud-based services utilising MiCADO*" [h]. As part of this activity German Data Center HKN, their business partner, is offering fully managed enterprise data clusters based on MiCADO. CloudSME expects an **additional contribution of 387,030 Euros to its turnover** by the end of 2020 as a direct result of commercialising MiCADO, as evidenced in document [i].

Impact on Government and Charity Sectors:
Within the COLA project public sector organisations, namely the Aragon Local Government (ALG) in Spain and [text removed for publication], a charity organisation funded by the UK Arts Council, have also benefitted from the CSSP coupled with MiCADO [b]. These organisations run data intensive web applications for which resources are managed and optimised by MiCADO.

Applications offered by ALG via its public company SARGA – which "*acts as manager of all public infrastructures and services related to agriculture and environment*" – utilise the CSSP and MiCADO, and the technical solutions provided by the CPC team "*have improved the recommendation engines of the Aragón Government in order to **provide better services to the people of Aragón and to result in higher general satisfaction within the people of the region***" [j]. SARGA and ALG representatives specify that: "*Based on the technical solution invented and developed by **Prof Kiss and his team**, the operational organization of our IT infrastructure have improved significantly*" such that "*we have **achieved more efficient processes related to software development and public services delivery***" [j].

By July 2019, [text removed for publication] had achieved an estimated increase of **100 (10%) new business partners/customers**, **212K Euros (7.5%) increase in turnover**, **20% more efficient business processes**, **3% increase in employment**, **50% reduction in time to market**, **10% increase in customer satisfaction**, and **4 (15%) new service offerings** as a result of applying MiCADO [b]. The company's planned exploitation of CSSP and MICADO is expected to have increased, by Jan 2022, to 200 (20%) new business partners/customers, 1.35 million Euros (15%) increase in turnover, 30% more efficient business processes, 6% increase in employment, 50% reduction in time to market, 30% increase in customer satisfaction, and 8 (30%) new service offerings, as a result of applying CSSP and MiCADO [b].

Company	Now				Exploitation plan five years			
	New Products / services	turnover	new employment	Internationalisation	New Products / services	turnover/year	new employment	Internationalisation
Company 1	1	200k	2	5	2	500k	3	8
Company 2	2	200k	2	5	5	1.000k	5	10
Company 3	2				2	30K	1.5	
Company 4	1	30k	1	2	1	200k	1	4
Company 5	3		2		50	4.000k	12	
Company 6	3	40k	2	5	5	70k	3	12
Company 7	1		1		2	500k	2	1
Company 8	2		4	6	3	100k	4	25
Company 9	1		1		5	250k	3	
Company 10	1	25k	1	1	2	100k	2	3
Company 11		100k	2			100k	2	20
Company 12	1				1	75k	1	2
Company 13	2	120k	2	2	3	700k	5	5
Company 14	1			2	4	50k	1	5
Company 15	1			3	2	150k	1	6
Company 16	1				5	750k	2	10
Company 17	1			1	3	1315k	3	15
Company 18			1	1	1	12k	2	3
Company 19	1		3		3	400k	10	
Company 20								
Company 21								
Company 22	3	250k	2	3	13	2.000k	20	2
Company 23		15k		2		75k		
Company 24					30	1.500K	4	10
Sum	**28**	**980K €**	**26**	**38**	**142**	**13.739K €**	**87.5**	**141**

Figure 1 - Reported impact figures by 24 companies in CloudSME on 31/03/2016

Partner	New/enhanced product/services		Increase in turnover €		Increase in turnover %		Increase in employment %		New contacts, partner/customers		More efficient business processes %		Reduction in 'time to market' %		Improved customer satisfaction %		Increase in profit €		Increase in profit %		Partners in new countries	
Period	2.5Y	5Y	2.5Y	5Y	2.5Y	5Y	2.5Y	5Y	2.5Y	5Y	2.5Y	5Y	2.5Y	5Y	2.5Y	5Y	2.5Y	5Y	2.5Y	5Y	2.5Y	5Y
Company 1	1	1	112,5K	400K	7,5	12,5	1	1,5	2	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	2
Company 2	1	1	37,5K	65K	N/A	N/A	0,5	1	2	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Company 3	1	1	37,5K	56K	20	30	20	20	20	20	100	100	N/A	N/A	Yes	Yes	10K	15K	20	20	2	2
Company 4	1	1	55K	82,5K	20	30	20	20	20	20	N/A	N/A	N/A	N/A	Yes	Yes	10K	15K	20	20	2	2
Company 5	1	1	50K	60K	1	1	1	1	5	5	50	50	50	50	50	50	10K	12K	2	2	1	3
Company 6	1	1	30K	50K	0,6	1	1	2	4	8	N/A	N/A	N/A	N/A	N/A	N/A	9K	15K	0,6	1	2	5
Company 7	1	2	80K	160K	2	4	3	6	4	4	100	100	30	30	10	10	40K	80K	1	2	4	4
Company 8	3	5	20K	250K	0,07	0,083	0,5	1,5	10	50	30	50	40	50	20	30	5K	60K	1	6	1	2
Company 9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Company 10	4	8	212K	426K	7,5	15	3	6	100	200	20	30	50	20	10	20	N/A	N/A	N/A	N/A	15	30
Company 11	1	3	15K	15K	N/A	N/A	1	3	1	3	-	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2	5
Company 12	2	10	32K	155K	2	10	7	27	5	25	Yes	Yes	Yes	Yes	Yes	Yes	-	15.5K	-	TBD	2	2
Company 13	3	5	560K	2243K	TBD	TBD	TBD	TBD	10	30	TBD	TBD	10	20	20	40	280K	1345K	TBD	TBD	5	15
Company 14	20	200	50K	200K	100	100	1	3	20	100	80	100	50	90	90	100	10K	60K	80	200	5	20

Period	New/enhanced product/services	Total increase in turnover €	Increase in turnover (average per company) %	New contacts, partner/customers	Increase in profit €	Partners in new countries
2,5 years	40	1291,5K	16,07%	203	354K	42
5 years	239	4162,5K	20,36%	476	1617,5K	92

Figure 2 - Reported impact figures by 14 partners (10 companies) in COLA on 31/08/2018

Wave	KPI Metrics								
	year after experiment	enhanced/new products/services	increase in turnover [K€]	increase in employment	new contacts/partner	more efficient business processes	reduction in time to product / market	improvement in customer satisfaction	increase in business practice	partners in new countries
Wave 1	1	19	1,645	13	>52	for 81%	10-80%	5-100%	for 75%	>17
	5	82	8,545	60	>190	for 81%	20-80%	10-100%	for 75%	>69
Wave 2	1	21	4,570	121	61	for 94%	for 83%	For all	for 89%	24
	5	40	29,960	330	216	for 94%	for 83%	For all	for 89%	88
Wave 3	1	20	8,665	16	81	for 79%	for 63%	For 84%	for 89%	29
	5	55	29,550	84	274	for 84%	for 68%	For 84%	for all	98
Overall	1	60	14,880	150	194	For most	For most	For most	For most	70
	5	177	68,055	474	680	For most	For most	For most	For most	255

Figure 3 - Reported cumulative impact figures by 52 companies in CloudiFacturing on 31/03/2019

5. Sources to corroborate the impact (indicative maximum of 10 references)

[a] CloudSME deliverable D4.6 IPR management/monitoring and exploitation/use 2, 31st March 2016, submitted by the CloudSME project to the European Commission, pages 13-21 containing exact impact figures of participating companies.

[b] COLA deliverable D3.1 First commercial exploitation and sustainability report, 21st December 2017, submitted by the COLA project to the European Commission, pages 30-33 containing exact impact figures of participating companies

[c] CloudiFacturing deliverable D7.2 First Report on Dissemination, Commercial Exploitation and Sustainability, submitted by the CloudiFactoring project to the European Commission, pages 22-24 containing exact impact figures of participating companies.

[d] CloudiFacturing deliverable D7.3 Second Report on Dissemination, Commercial Exploitation and Sustainability, submitted by the CloudiFactoring project to the European Commission, pages 32-35 containing exact impact figures of participating companies.

[e] Impact video by Hobsons Brewery and Company Limited. 23/09/2015

[f] Impact video by Podoactiva SL. 16/05/2017.

[g] Testimony from the Managing Director of Saker Solutions Limited.

[h] Testimony from CloudSME Managing Partner / CEO

[i] COLA deliverable D3.3 Final commercial exploitation and sustainability report, 30th September 2019, submitted by the COLA project to the European Commission, page 24 containing forecasts by CloudSME UG regarding the expected utilisation of MiCADO for 2019-2021.

[j] Testimony from the responsible Project Manager at SARGA and the Head of Design and Development at the Government of Aragon.