Integrating agent based simulation in the design of multi-sided platform business model: a methodological approach

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Abstract—**The sharing economy emerged in recent years as a model disrupting the approach to traditional B2B and B2C value chains by giving access to underutilized resources at a fraction of the cost to whom cannot or do not want to buy new products. In this context, multi-sided platforms (MSPs) play the pivotal role of providing the environments and the technological infrastructures able to match make the needs of manifold user insisting on them. The manufacturing sector didn't remain untouched by this trend, but still struggle to set up the value drivers supporting companies in the change. How can companies move towards new business models based on MSPs? How can they be supported in the value creation by the platforms? Aim of the proposed study is to present a MSP platform and related ecosystem for the automation sector, designing its business model and analyzing the tackled limitations and potential improvements. The selected case study brought to the definition of a methodological approach to MSP business model design based on both qualitative and quantitative analysis of the dynamics ruling the platform ecosystem, combing a static conceptualization of the MSP business model canvas with an agent-based simulation model, for capturing and emulating the behavior of the MSP stakeholders with the purpose to validate the sustainability of the platform ecosystem.**

Keywords—multi-sided platfor business model, business model design, business model simulation, agent-based simulation

I. INTRODUCTION

The sharing economy has emerged in recent years as a disruptive approach to traditional B2B (and B2C) business models by giving access to underutilized resources and creating communities of actors that can exchange through the platform information, data, assets [1]. As an instrument fostering this paradigm change, platform models have strongly proliferated over the past years, reducing transaction costs and facilitating exchanges that otherwise would not have occurred [2]. B2B platform models have been diversely defined as "business models that allow multiple sides (producers and consumers) to interact [...] by providing an infrastructure that connects them"

[3] or, in a more complex way, as: "a governance structure [...] that determines who can participate, what roles they might play, how they might interact and how disputes get resolved" and "an additional set of protocols or standards[...] to facilitate connection, coordination, and collaboration" [4].

Digital platform businesses are increasingly emerging, also supported by European Commission considering them "the engine of Europe's growth, industrial transformation and job creation"[1]. Many initiatives (Big Data and Factory of the Future Public-Private Partnerships, COSME, Connected Factories, H2020 funded projects) have been launched in the last few years promoting and supporting the creation and deployment of B2B digital platform for industrial manufacturing leadership, with an investment of ca. 140 M€ public funding [5]. Platforms enable value-creating interactions between different parties (e.g. customers and suppliers) expanding markets by bringing together knowledge flowing from different parties. Equipped with appropriate business models, digital platforms may foster the creation of ecosystems of stakeholders in a multi-sided marketplace. These ecosystems enable the creation of new innovative products and services and accelerate the development of worldwide standards. Nevertheless, some critical aspects are still hindering companies' transformation of their business strategy to compete with current market trends:

- a lack of interoperability, responsible leadership and regulation affects the wide adoption and federation of such platforms at industrial level[2];

- exploitation strategy and adoption roadmap are often not effective and lack of supporting models [6];

- design tools for platform business model are limited to qualitative and not quantitative analysis and results, thus discouraging potential platform's adopters to invest in the business model transition [6], [7].

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[1] https://goo.gl/8wgtLR last access on 15/03/2018
[2] https://goo.gl/nf21XD last access on 15/03/2018

Aim of this paper is to investigate the design of a business model for a multi-sided platform (MSP) for the automation ecosystem, developed within the European project DAEDALUS, and define a methodological approach in order to go beyond the qualitative approach proposed by business model canvases, taking advantage of the business model simulation tool developed within the European project vf-OS.

II. METHODOLOGIES FOR BUSINESS MODELLING

Traditionally, most business models tend to derive from a mono-organizational logic, with companies that remain reluctant in sharing proprietary information with partners and users. Companies that in the recent past were able to break with the established logic in their industries reached exceptional success accessing knowledge and competences from suppliers operating in completely different markets. Involving different communities with really heterogeneous roles and interests means working in a multi-sided environment, thus leveraging on network effects. There is growing interest in the economics of multi-sided platforms (MSPs), which get more than one side on board and enable interactions between them (e.g., Airbnb, eBay, Uber, XBox, etc). MSPs enable the direct interactions between two or more distinct sides and each side is affiliated with the platform (with affiliation, an investment in the platform in the form of fee or resources expense is intended) [8]. The pioneering models of MSPs all treat "multi-sidedness" as a given characteristic of the relevant industries and firms [9] [10] [11] [12] [13] [14].

MSPs are nowadays present in different and variegate industries, in particular in high-tech businesses driven by information technology [15]. Microsoft, Google, Intel, Qualcomm and Cisco are some of the thousands of other companies that based their business on platform leadership. Platform models have strongly proliferated over the past years, reducing transaction costs and facilitating exchanges that otherwise would not have occurred [1]. These models have been diversely defined as "business models that allow multiple sides (producers and consumers) to interact by providing an infrastructure that connects them" or, in a more complex way, as a governance structure that determines who can participate, what roles they might play, how they might interact and how disputes get resolved" and "an additional set of protocols or standards to facilitate connection, coordination, and collaboration. Other research [16] [17] identified as platform a set of standard components on which buyers and sellers coordinated their efforts, whereas defined it as an architecture of correlated standards composed by modular and complementary assets. Platforms are usually managed by a leader company, defined as platform leader [18]. This is an actor who drives innovation for an evolving system, composed by separately developed elements (products and/or services). The platform leader is a company which performs a function that is essential to a broader technological system and solve a business problem for different and independent companies and users. These definitions are in accordance with the one provided by Osterwalder [19], who stated that a multi-sided platform brings together two or more distinct, but interdependent, groups of customers. The platform allows the interactions of the different actors and generates value, facilitating their interaction. The platform does not make sense to exist, without the presence of all actors that, in sake of this, can be defined as complementors[3]. The platform owner, complementors and end-user form the platform ecosystem.

In [19], the Business Model Canvas is proposed to depict the MSP business model. Though this tool has been adopted to manage different customers' relationships, several tools have been proposed by other authors or consulting agencies to support companies in the business model definition. Though in this study the focus is not on the definition of single complementors business model (having different value propositions one from the others), but on modeling the business transactions of the platform. To this purpose, only business models devoted to MSP have been considered. A Business Model Kit is proposed by Board of Innovation[4], composed by 16 building blocks to be filled in with details on different stakeholders and value elements, resulting in a marketing tool to communicate business model to different audiences. Leanstack[5] proposes Lean Canvas, adapted from the Business Model Canvas, together with a procedure to be followed for filling in the 9 building blocks starting from modeling the users, then the customers and finally the derivative currency exchange rate. The Lean Canvas introduces the problem understanding phase, the definition of key metrics and of the unfair advantage, at the expense of key activities and key resources, key partners and customer relationships.

Eventually, the Platform Design Toolkit [20] has been developed by Simone Cicero and his team to support companies in defining their platform vision, the core and ancillary value proposition, its infrastructure and core components, and transactions dynamics characterizing the platform ecosystem. The toolkit relies on the concept that "platforms leverage ecosystem to win over competition", resulting in several guided tools to design the ecosystem, the platform and the business model. Based on the Cicero's team motivation and vision of the platform ecosystem, the practical guide for using the toolkit and the elements that the toolkit allows to analyse and better understand, the authors opt for the adoption of this toolkit to design the Daedalus MSP business model.

III. CASE STUDY: APPLICATION OF PLATFORM DESIGN TOOLKIT FOR THE DESIGN OF DAEDALUS PLATFORM BUSINESS MODEL

A. Introduction to Daedalus case study

In the last 30 years, the industrial automation world has seen a fast technology innovation for both what concerns the hardware and the software domain [21]. Indeed, more sustainable and efficient production systems, able to keep pace with the market evolution, are fundamental in the recovery plan aimed at innovating the European competitive landscape. An

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[3] Complementors: "the developers of a complementary products, which the greater sales of one increase demand for the others. A and B are complements if the valuation by consumers of A and B together is greater than the sum of the valuation of A alone and of B alone" [25].

essential ingredient for a winning innovation path is a more aware and widespread use of ICT in manufacturing-related processes [22]. This transition has to be fostered by technological solutions able to meet the required degree of functionalities expected by Industry 4.0 industrial requirements. On top of that, a strenuous work has to be done in order to carry the industrial domain in the paradigm changing shift required to enable this transition.

DAEDALUS is a H2020 project that aims at the creation and deployment of an Automation Ecosystem for a multi-sided market based on a new generation of distributed intelligent devices that, existing both in the real and in the cyber world, can be aggregated, orchestrated and re-configured to exhibit complex manufacturing behaviors that optimize the performance of future shop-floor. The DAEDALUS platform fosters the creation of a multi-sided market in the automation industry, in which several distinct groups of users and complementors can be involved since they value each other's participation on board the same platform in order to generate an improved economic, environmental and social value. The industrial automation sector has very peculiar characteristics that need to be considered within an innovative business model for the ecosystem if the transformation into a digitally-centered market is to be justified.

The DAEDALUS platform can be defined as an integrated platform [23], providing the technologies on which the complementors of the Automation value chains can build their products/services and those that facilitate the exchange and transactions between users and producers. These are all part of an Automation value chain. Who adopt the technologies proposed by DAEDALUS form and characterize the DAEDALUS ecosystem. DAEDALUS business model will propose a multi-sided ecosystem, composed by the platform owner, a number of complementors providing content to the platform but not involved in platform-mediated transactions and the platform users.

Aim of this research is thus to investigate the business modeling design of DAEDALUS MSP by applying the methodology presented in [20]. DAEDALUS platform, as well as MSP in general, requires a specific business model, which depends on the ecosystem that it "controls" and on the technology on which the platform is built on. For this reason, first the DAEDALUS actors/complementors are introduced, which concur in the development of automation solutions. Then, the main technologies proposed by DAEDALUS, pave the way for the DAEDALUS platform business model presentation, defined applying the methodology introduced by Cicero [20].

Technological advancement per se is not able to demonstrate the full potential of innovation breakthrough proposed by projects like DAEDALUS [24]. To be effective, this has to be followed by the definition and implementation of actions supporting the change of mentality in the automation sector, demonstrating the full feasibility of the transition and the practical results it can bring.

B. Daedalus ecosystem

Complex value chains characterize the current automation environment, where different companies provide both products and services, and collaborate to generate value for the final customer. In these value chains, the influence of the upstream companies is relevant on the final product, whether we are talking about machines, entire lines or plants. In particular, the choices on automation controls have a significant influence in what will be the final automation solutions. To obtain an automated solution, which satisfy product and process needs of the customer, it is necessary a strong integration between all the constitutive elements, with particular focus on reliability. Moreover, reliability and integration should not preclude the opportunities of future changes and of scalability. The management of these aspects is critical, in particular in this kind of environment, often characterized by closed systems, where the integration is easy and cheap only through the utilization compatible elements (same vendors). For these reasons, the choices about partners and solution's elements have relevant impacts on the business model of the complementors and on final customers' costs and performance.

This complex environment is currently populated by five macro-categories of stakeholders: component suppliers, automation solution providers, equipment and machines builders, system integrators, plant owner. These macro-categories, which are the main complementors of the DAEDALUS ecosystem, are the most relevant subjects concurring in the design and development of an industrial automation solution in which different elements, both hardware and software, are integrated in mechatronic systems, each one characterized by different functionalities and level of complexity.

The main motivation for the introduction of the DAEDALUS platform in the automation ecosystem born from the awareness that the current technological advancements are not enough to satisfy the new needs of the automation end users. A complete change in the methodologies, applied by the automation stakeholders, is necessary to satisfy the new manufacturing needs, and should be supported by a proper ecosystem based on a multi-sided platform. This can be pursued through the involvement of all the main stakeholders of the automation domain, which will be interconnected through the standardization and the interoperability introduced by the platform.

The technological platform of DAEDALUS thus becomes the Economic Platform of a multi-sided ecosystem, where the creation of added value products and services by components suppliers, equipment & machines builders, systems integrators, application developers and service providers will go beyond the current limits of manufacturing control systems and propose an ever-growing market of innovative solutions for the design, engineering, production and maintenance of plants' automation [25].

The DAEDALUS platform will unlock the opportunity to the deployment of an orchestrating intelligence implementing multidisciplinary optimization algorithms through a CPS-based distribution of intelligence. This will guarantee a multi-level maximization of the efficiency at all the factory levels. The

platform is based on core enabling elements, founded on the new evolution of the IEC-61499 standard. These are DAEDALUS Integrated Development Environment (IDE), IEC-61499 runtime, DAEDALUS Reference hardware controller, IEC-61499 Hardware/Software "CPS-izer" and the DAEDALUS digital market-place, and they represent the main elements of the platform through which the value proposition is generated. Each element is provided to different complementors, each one interested in a different value proposition.

By the introduction of the platform in the automation market, the stakeholder's behaviors and the roles is modified within the DAEDALUS ecosystem:

- Automation solution providers: they can be considered as the main competitors of the Daedalus platform owner. They can continue to promote current solutions and methodologies, trying to stop the development of the platform, or they can adopt the IEC-61499 standard, implementing their own "dialect" and tools, to create a new IEC-61499 automation ecosystem, in parallel with the DAEDALUS one. Another alternative, it is the change of their main business, from the development of complete control solution (hardware and software) into the development of only hardware (performing the role of Cps-izers producers), leaving the software side to other specialized actors.

- Components suppliers: thanks to the introduction of the platform and the adoption of the IEC-61499 standard, become capable to release more functional, intelligent and independent components, able to work in flexible and orchestrated production systems. Components are not anymore simple and basic elements, but CPS, which are mechanical and electronic subsystems equipped with on-board distributed intelligence. In the DAEDALUS ecosystem, the components suppliers have the possibility to add applications and software to their products, thanks to the platform elements, adding value and increasing the revenue opportunities.

- Equipment and machines builders: they will develop and produce complex manufacturing systems as aggregation of CPS, focusing their effort on the assembling and orchestration of the automation tasks of these composing elements. Moreover, thanks to the IEC-61499 and the Daedalus platform, they will be able to develop software libraries and applications, exploiting also those created by all the other complementors, thus proposing on the market machines with much more advanced functionalities compared with current solution. Thanks to the more advanced components and the independency of the software from the hardware, machines and equipment builders can provide advanced functionalities, with lower efforts in terms of integration, adaptation and interfacing.

- System integrators: providing for free information material, training and support, the platform owner must involve and attract system integrators to propose and use DAEDALUS-based technologies. In the initial phase, the DAEDALUS platform is expected be focused on a restricted number of system integrators, establishing agreements for close collaboration, to facilitate the support for the development of solutions for end-customers. With these "strategic" partners the platform could also consider to extend its influencing activity by further incentivizing the adoption of IEC-61499 compliant applications by providing for free CPS-izers to be used for machine revamping.

- Plant owners: after having recognized their needs and identified as solutions the DAEDALUS technologies for innovating and transforming their production system, plant owners must be supported by system integrators. Plant owners usually has not enough competences to go over the technological gap to initiate the change. They can push the evolution through commitment and resources, but they will almost certainly require the collaboration of external actors.

In addition to the traditional stakeholders, in the DAEDALUS ecosystem, new complementors have the possibility to act and support the value creation:

- Cps-izers producers: they are necessary to upgrade the existing systems based on IEC-61131 technologies and to complete exploit the benefits of the platform components. The platform provides a reference for Cps-izers development, leaving the production to other external actors. The latter can be an automation solution provider or a hardware producer, which desire to extend their products portfolio and business. In the initial platform development, these actors are fundamental for the initial platform development. Probably, they will be a close partner of the platform owner.

- Application developers: they develop applications, libraries, function block and algorithms for equipment, data elaboration/aggregation algorithms, domain specific functionalities, orchestrating applications for common scenarios, etc. Application developers will provide IEC-61499 compliant applications for general purpose usage scenarios, customizable by component suppliers, equipment & machine builder, system integrators and/or plant owners, for their specific projects. Added value is provided by guaranteeing special functionalities based on specific competence, quality of implementation, performance achieved.

- Service providers: they can supply different in-cloud services. A service example is the opportunity to test the optimization logics during the design phase and to reduce the time for the test and commissioning of the entire control system.

C. Daedalus business model

The Business Model design has been carried out by relying on the modelling procedure developed by Cicero [20] in its work "Platform design toolkit". The modelling procedure has been partially adapted to the automation case carrying out the following steps:

1) Platform ecosystem classification: identification of all the actors in the ecosystem and the role they can play in;

2) Motivation matrix creation: it supports in the understanding on which are the incentives for the actors of the ecosystem to participate and exchange value;

3) Transaction board creation: map of the potential transactions amongst platform users;

4) Platform design canvas: it is the core of the methodology, that represents the overall platform's dynamics starting from the exchanges that are happening between actors and the key resources. It also supports in the identification of the enabling and empowering services that the platform provides to the complementors, understanding if the platform is doing its job of sustaining the ecosystem in the value creation and evolution process.

1) Platform Ecosystem classification

The first step in modelling the DAEDALUS platform business model conceived mapping the different actors accessing the platform under 4 groups as represented in Table I. These stakeholders have then been mapped into a dedicated canvas, as depicted in Fig. 1.

2) Motivation matrix creation

As a second step, the *Motivation Matrix* has been used as a reference tool supporting the identification and tracking (i) of the value proposition of the platform towards the single complementors, and (ii) of the value transferred among the actors. The Motivation Matrix is indeed thought to dig deep into the motivation that pushes entities in the ecosystem to participate and join the platform. It is intended to track the main advantages in participating in the ecosystem through the platform (namely needs they can meet, opportunities they can find and such positive outcomes) versus playing alone and also what each entity can "give to" others.

Entities involved in an ecosystem may find two macro-types of incentives in joining it and starting to produce value through the platform: intrinsic motivation (advantages in joining the system vs. playing independently on the same market) and give-take opportunities (possibility to build relationships, transact and trade value with other players, through the platform).

In the matrix (Fig. 2), the roles of *Partners*, *Peer Producers*, and *Peer Consumers* - previously mapped in the Ecosystem Canvas – have been reported in the first column and row. In the diagonal, the intrinsic motivation of the corresponding entity (the main advantages in participating in the ecosystem through the platform) are mapped, while in the other cells, what the entity on the axis on the left can "give to" the entity on the upper axis is reported.

3) Transaction board creation

The "Transaction Board" tool has been used to map interactions mediated by the platform, considering the

exchanged good among stakeholders, the currency/value units and the channel or context where this exchange may happen.

With respect to the original "Transaction Board"[6] two more columns have been added with the aim of directly considering revenue and costs arising for the platform (Fig. 3). The designed transactions take into account the ones that will be managed through the platform marketplace, thus related to applications and services or to updates and addition of new functionalities to machines. Furthermore, the possible exchanges that could arise among component suppliers and equipment/machine developers that could be interested in developing their own device, thus requiring to acquire reference knowledge form the competitors, have been mapped as well.

TABLE I. PLATFORM ECOSYSTEM STAKEHOLDERS

| Category	Description	Actors accessing the DAEDALUS platform
EXTERNAL STAKE-HOLDER	Entities that have a specific interest in platform success or failure, in controlling platform externalities and outcomes	• Government/EU commission • Industrial software providers • Univ./Research centres • Automation solution providers
PARTNER	Professional entities seeking to create additional professional value and to collaborate with platform owners with a stronger relationship	• System Integrators • CPS-izer developer (component suppliers)
PEER PRODUCER	Entities interested in providing value on the supply side of the ecosystem/marketplace, seeking for a better performance	• Service providers • Application developers • Equipment/machine developers • Component suppliers
PEER CONSUMER	Entities interested in consuming, utilizing, accessing the value that is created through and on the platform	• Plant Owners • Equipment/machine developers • Component suppliers
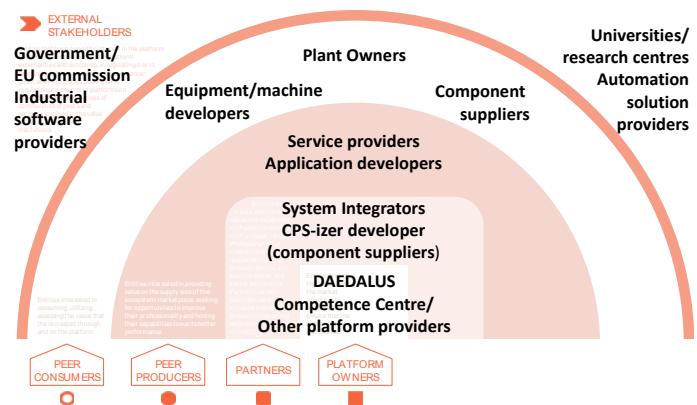
Fig. 1 DAEDALUS ecosystem canvas. Larger circles (or "zones") mean that one group is normally wider (eg: consumers) than another. Also, the closer a group is to the owners the more strategic the collaboration is between the two, according to potential impact for platform success. Derivative work of [20].

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gives to →	System Integrators	Application developers	Service providers	Equipment/ machine developers	Component suppliers	Plant owners
System Integrators (Pa PP PC)	• Simplified machine integration & scale-up • Provision of higher added value services • Higher revenue opportunity	• Feedback/needs • Reputation	• Feedback/needs • Reputation	• Feedback/needs • Reputation	• Feedback/needs • Reputation	• Provision of higher added value services • Value for money
Application developers (Pa PP PC)	• New functionalities • Simplified integration	• API, IDE and SDK for fast application development • High visibility sale channel • Reliability in transactions • Standard based solutions for replicable exploitation	• Feedback/needs • Reputation	• Better performances, new/custom functionalities	• Better performances, new functionalities	• Better performances, new/custom functionalities
Service providers (Pa PP PC)	• New services	• App validation • New services	• Sale channel providing high visibility; • Reliability in transactions • Standard based solutions supporting replicable exploitation	• Machines virtual commissioning • New services	• Component virtual commissioning • New services	• New services • Machines virtual commissioning
Equipment/ machine developers (Pa PP PC)	• Simplified machine integration & scale-up;	• Feedback/needs • Reputation	• Feedback/needs • Reputation	• Increase perceived product value • Extended customer services • Reduced design/development efforts	• Feedback/needs • Reputation	• Higher functionalities, integration & scale-up • Value for money • Minor costs opportunity
Component suppliers (Pa PP PC)	• Components with extended functionalities	• Feedback/needs • Reputation	• Feedback/needs • Reputation	• Increase value & intelligence of components; • Room for machine improvement	• Component intelligence increase • Increase perceived product value • Higher revenue opportunity • High visibility sale channel	• Components with extended functionalities • Value for money
Plant owners (Pa PP PC)	• Feedback/needs • Reputation	• Feedback/needs • Reputation	• Feedback/needs • Reputation	• Feedback/needs • Reputation	• Feedback/needs • Reputation	Support the creation and deployment of more efficient, flexible, orchestrated production systems easy to be integrated, monitored, updated

□ What could the entity on the vertical axis on the left give to the entity on the horizontal axis on top? □ Advantages in participating in the ecosystem (needs, opportunities) through the platform

Fig. 2 DAEDALUS motivation matrix. Derivative work of [20].

E1	Transaction/ Interaction	E2	Currency/ Value unit	Channel	Benefit for platform	Platform associated cost
• System Integrators • Equipment/machine developers • Component suppliers	• Buy application • Leave review	Application developer	• Money • Reputation	Marketplace	• Transaction fee • Publishing fee • Reputation	• Marketplace hosting • Application review • IDE/SDK update
• System Integrators • Equipment/machine developers • Plant owners	Buy/rent Services	Service provider	• Money • Reputation	Marketplace	• Transaction fee • Reputation	• Marketplace hosting • Service review
• System Integrator • Plant owners	Buy/download software update/functionalities	• Equipment/ machine developers • Component suppliers	• Money • Customer satisfaction	Marketplace	• Transaction fee • Supplier association fee	• Marketplace hosting
Component suppliers	Buy/download reference knowledge	CPS-izer developers	Money	Marketplace	• Reputation • Visibility • Transaction fee	• Marketplace hosting • Reference CPS-izer • Guidelines
Equipment/machine developers	Buy/download reference knowledge	Hardware controller developer	Money	Marketplace	• Reputation • Visibility • Transaction fee	• Marketplace hosting • Reference CPS-izer • Guidelines
ALL	Share knowledge in problem solving	ALL	Knowledge, methods, approaches	Platform community	• Reputation • Visibility	• Platform community hosting

Fig. 3 DAEDALUS transaction board. E1 and E2 are Entities interacting. Derivative work of [20].

4) Platform design canvas

The analyses carried out within the previous phases have been eventually aggregated in the Platform design canvas proposed in Fig. 4, and structured with the following elements (the platform stakeholders and plant owners have been already described):

- Transactions: a transaction is a sub-action (part of a more complex "experience") during which value is either created, provided, transferred or traded among two (most often) or more entities. DAEDALUS envisages two main types of transactions: the first is monetary and related with the software goods that are exchanged through the platform (applications, services, runtime); the second ones are intangible assets that platform complementors delivery thanks to reviewing systems typical of marketplaces.

- Channels & Contexts: allow exchanges to happen inside the platform with negligible friction. They are key to enable value creation: the platform should actively create and improve them all the time. The main channel provided by the DAEDALUS ecosystem is the

marketplace where applications, services, updates are respectively bought, exchanged and downloaded.

- Enabling services: services targeted to help partners to generate value from their professional capabilities, gain new markets, reach new opportunities and visibility and gain decisive improvement as professionals. In the case of DAEDALUS, these are considered as those services enabling to support system integrators and CPS-izers producers respectively in the integration of DAEDALUS compliant systems and in the spreading of the DAEDALUS concept within the automation domain.

- Empowering services: services targeted to help peer producer start performing transactions, hone their capabilities, get better on the platform and start the evolution phase. The DAEDALUS platform is intended to provide support in the development of application and services compliant with IEC 61499 standards by means of dedicated consultancies, training and reference software examples.

- Other services: in many cases platforms provide "complementary", traditionally organized (industrialized) services for peer consumers. They complement the value exchanged and represent strong single user utility. Similarly to empowering services, training and support will be also conceived for those customers intended to shift towards IEC61499 compliant manufacturing systems.

- Core Value Proposition: is the primary value that the platform seeks to create for its core target. It usually targets Peer Consumers since they're normally the wider peer segment and the segment looking to "consume" value. Especially in market-networks and in more niche-oriented contexts, where the volume of transaction is lower and value of the transaction is greater, peer producers or partners might be the primary targets of the Core Value Proposition. In the case of DAEDALUS, platform value proposition relies on unveiling potentialities of IEC61499 and letting it available to the complementors of the automation domain.

- Ancillary Value Propositions: the ancillary value proposition is a secondary value that the platform seeks to enable. Ancillary value propositions can be targeted to the same target segment of the Core Value proposition or to a different one. Often, platforms complement a core value proposition for the demand side of the platform with one targeted to the supply side. DAEDALUS provides the whole environment that enables not only the actual interaction among players in a multi-sided ecosystem, but also the means required to increase their visibility within the automation domain.

- Infrastructure & Core Components: are controlled and owned by the platform owners and governed according to the platform governance. They are assets that ensure that the platform works and it is usable by the ecosystem, they can be tangible (such as with an application or a venue) and intangible (such as with a shared standard). DAEDALUS identifies as main components of the

platform Business model the key elements of a IEC 61499 driven environment thus the standard itself, the standard enablers (Runtime, CPS-izers) and the channels and functionalities enabling its diffusion.

IV. BUSINESS MODEL DESIGN CANVAS AS AN INPUT FOR AGENT-BASED SIMULATION

The business model canvas provides a static conceptualization of the future MSP activities, but presents limitations for analyzing the financial flows produced on the interactions between the platform's stakeholders. The developed Business Model and the related implementation strategy is a convincing starting point for paving the way for an effective implementation activity supporting the maximization of probabilities of DAEDALUS adoption. However, the adopted methodology still follows an approach that is able to provide only a qualitative analysis of the dynamics ruling the platform ecosystem. Both the motivation matrix and the transaction board have been easily mapped in the proposed business model canvas, but as the more widespread Osterwalder canvas [19], costs-revenues streams can be only mapped in a qualitative way. The transaction board the authors adopted has been modified adding two columns in order to map, for each entities' interaction/transaction, which the main benefits for the platform and their related associated costs are. However, in order to provide a quantitative analysis of the defined business model scenario it is necessary: (i) a quantitative approach enabling to evaluate how the depicted business model performs under different input scenarios; (ii) an extension/refining of the adopted canvases enabling to funnel the qualitative evaluations into inputs for a quantitative assessment; (iii) a more detailed analysis of transactions driven by the DAEDALUS platform in order to enable the quantification of each transaction, the type of access to the platform, the possibility to download and manage content, etc.

Simulation models can provide the infrastructure to run quantitative and dynamic analysis of platform flows. Agent-based simulation is a good approach for modeling such kind of interactions. vf-OS "Virtual Factory Operating System" H2020 project used an agent-based simulation model, as a complement to the traditional business model canvas, for capturing and emulating the behavior of the multi-sided marketplace stakeholders with the purpose to validate the sustainability of the platform ecosystem. That sustainability is based on financial performance indicators not only of the platform provider but also of every single partner of the ecosystem as far as, in MSP, the success of a partner strengthens the others making a stronger value proposition and a healthier ecosystem. Along with financial indicators per stakeholder, other quantitative performance indicators are generated such as the number of partners joining the platform, the number of products or services offered, sold or purchased in average per stakeholder in the marketplace, that represent the growth evolution of the ecosystem.

As it is the case with DAEDALUS, the vf-OS business model simulation requires the identification of the different stakeholders of the platform, that in vf-OS case the stakeholders are (i) app developers, (ii) service providers, (iii) manufacturing and logistics providers, (iv) manufacturing and logistics users buying apps, assets and services, and (v) vf-OS Inc. managing

PLATFORM OWNERS

This category refers to the "owners" of the Platform: ultimately this set of players and the realization of the market, and are ultimately responsible production.

- DAEDALUS
- DAEDALUS competence centre
- Other platform providers

Enabling Services (Platform to Partners)

Services targeted to helping partners generate value from their professional market, opportunities and vision, and decisive improvement as providers.

- Training
- Marketing events

Core Value Proposition

Support the creation and deployment of more efficient, flexible and orchestrated production systems easy to be integrated, monitored and updated

Transactions

These transactions happen between two exchanging or transferring ownership of a providing elements of reputation, trust, labour/work or enabling access to resources.

- Pay for Runtime
- Pay for downloaded applications
- Pay for services
- Leave review of application/service
- Share problem and needs

PARTNERS

Partners are essentially professional entities that seek to create additional professional value to collaborate with platform at a larger stage of relationship. Typically, partners are professional value creators that tend to specialize in one product/service and become a provider within time. Partners actively facilitate, cater, enhance collaboration by acting as brokers or contributors.

System Integrators

CPS-izer developer (component suppliers)

PLATFORM STAKEHOLDERS

Are the entities that have a specific interest in controlling companies, in exercising rights in the platform.

- Industrial software providers
- EU commission
- Governments
- Universities/research centres
- Automation Solution Providers

Empowering Services (Platform to Peer Producers)

Services targeted to helping peer producer hone capabilities, get better and generate platform.

- Training/Support
- Applications examples

Other Services (Platform to Peer Consumers)

services can be provided to peer consumers as complementary of the experiences provided by the ecosystem through the platform.

- Training/Support

Ancillary Value Propositions

A secondary value that the platform seeks Core Value targeted to a

- Provide an environment supporting reliable transactions in the automation domain;
- Increase suppliers visibility and open-up new markets

Infrastructures and Core Components

owned by the platform to the physical assets, tangible components that ensure the platform smoothly and in

- Runtime
- Developers' kit/IDE
- Marketplace
- Built-in functionalities/ applications
- (CPS-izer)
- IEC61499

Channels & Contexts

contexts that evolve into wider or other channels. A channel should be available to a and transactions easier than a channel must to happen

- Download applications (Marketplace)
- Access services (Website/Marketplace)
- Update machines/components (Marketplace)
- Download Runtime (Website/Marketplace)

PEERS (producers)

Entities interested in providing their professionality and refining their capability and performs

Application developers
Service providers

Equipment/ machine developers

Component suppliers

PEERS (consumers)

Entities interested in consuming, utilizing, accessing the value that the is created on the platform

Plant owners

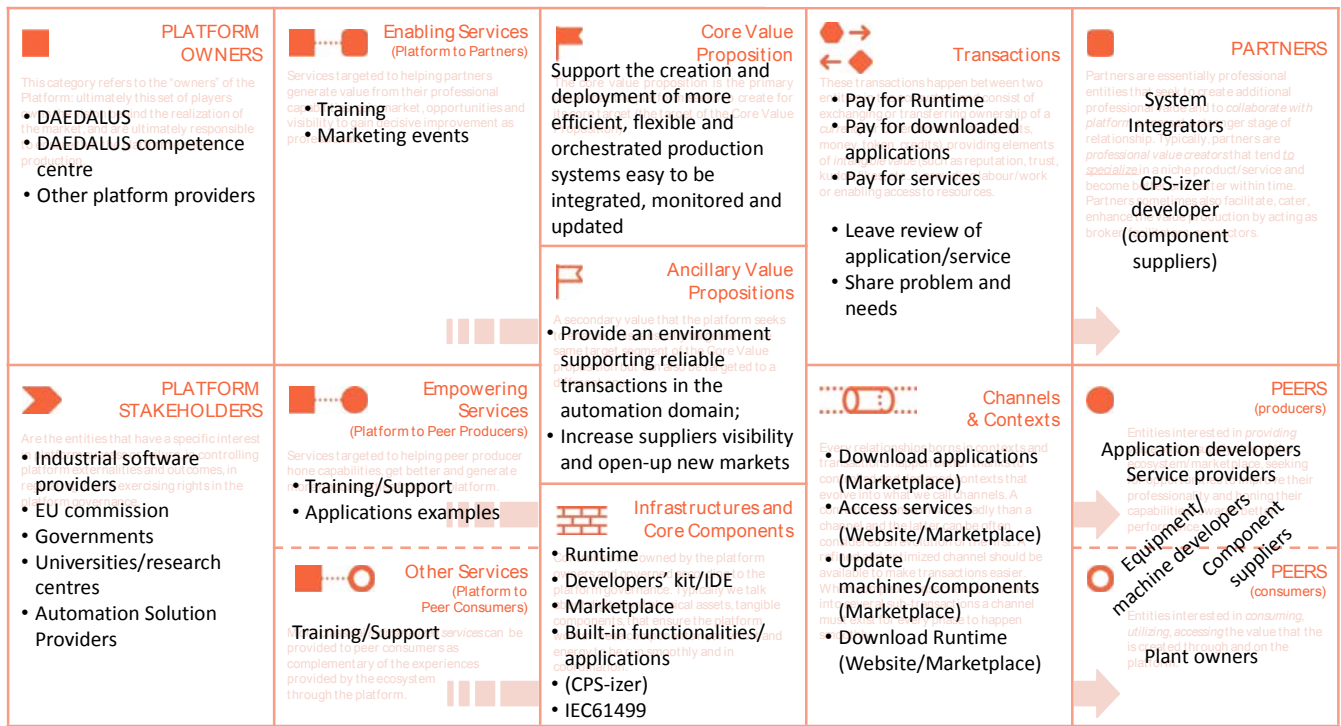PLATFORM VISION → ECOSYSTEM DYNAMICS

Fig. 4 DAEDALUS platform design canvas. Derivative work of [20].

the platform and marketplace. These can be easily mapped to DAEDALUS' counterparts.

The vf-OS business model simulation represents each of stakeholder as an agent, describing its behavioural lifecycle, from the moment stakeholder individuals join the platform until they decide to leave it, with state-charts and stochastic business rules. vf-OS business model simulation is parametrized so that some of the previous and other indicators could be modified before running the simulation.

The simulation execution shows lively the evolution of the market according to a range of financial and growth indicators. There are indicators evaluating the health of each stakeholder type, how much providers are earning while offering products and services, and how much are customers spending according to the different kind of apps. Finally, there are indicators concerning the financial results that the market evolution of the scenario execution has generated for vf-OS Inc. Those performance indicators cover revenues, expenses, ROI or the breakpoint event. This quantitative information can become a valuable input for assessing the performances that can be reached through the business model implementation and as a starting point for the definition of complementors' business plans.

An extract of some of the indicators that were captured in the simulation model is shown in Table II, black text. DAEDALUS platform stakeholders presented in §B can be mirrored in the vf-OF platform ones, as reported in Table II, first column, red text. The dynamics captured within the vf-OS ecosystems are similar to the dynamics generated in the DAEDALUS ecosystems and

mapped in the transaction board (Fig. 3). In Table II the DAEDALUS dynamics have been mapped in the second column adding text in red color. This exercise allowed the authors to verify the feasibility of applying vf-OS business model simulation strategy to the DAEDALUS platform, being in the context of MSP for the manufacturing sector and the stakeholders/complementors of the two considered ecosystems similar.

TABLE II. INDICATORS INPUT FOR THE vf-OS SIMULATION MODEL

Stakeholder	Some of the dynamics captured
Software Developer Agent, Service Provider Agent and Manufacturing and Logistic Provider Agent (providers) → Equipment/machine builders Components suppliers Automation solution providers Services providers	• the rate at which developers generate vApps for vf-OS (→ DAEDALUS software/hardware components) • pricing model according to the app complexity • population evolution according to market • applications review costs
Manufacturing and Logistics User Agent (consumers) → System integrators Plant owners	• population growth • buying apps (→ software) according to developers' expertise and reputation and download updated functionalities • licensing model of the app and components • cross-buying dependencies between assets
vf-OS Inc. (platform provider) → Platform owner	• the margin on app/asset sales charged to stakeholders • expenses • revenues from other services • marketplace hosting

V. Conclusions and Next Steps

Beyond most traditional business model definition strategies, this study allowed to better understand and to formalize the relationships and partnerships mechanisms amongst the actors accessing MSPs. This has been done using as test case the platform business model developed for the Daedalus ecosystem.

The adoption of the canvases designed by Cicero et al. [20] showed that this instrument provides a substantial methodological approach for the qualitative definition of business model scenarios dedicated to MSPs. Splitting the business model development in several canvases allows to focus on specific sections and to go deeper in details of their design. Though, the adoption of those instruments still lacks in achieving a quantitative approach enabling to assess to which extent the developed business model is able to remain sustainable under the dynamic evolution of the boundary conditions.

In the vf-OS Inc. project, an agent-based simulation methodology has been adopted to model and assess the sustainability of the designed MSP. This methodology can be used as starting point for the development of a simulation model enabling the assessment of MSP in the manufacturing domain.

As a following step, the DAEDALUS project will be use as case study for the validation of the proposed simulation model and, in doing so, the canvases proposed in [20] will be further extended by developing a methodology guiding the user towards the quantitative definition of the business model elements required to run the simulation model.

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