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Value Proposition of a Resource Description Concept in a Production Automation Domain

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Abstract

A Resource Description concept aims to support rapid design and reconfiguration of modular plug-and-produce type production systems. The developed information models for resource description describe formally and comprehensively the capabilities, interfaces, executable capabilities, and other characteristics of production resources. The proposed information model produces an integrated container of the resource information, as an extended and detailed electronic data sheet, and it can be applied in several phases of system design and commissioning. This paper introduces, through a set of value propositions and use cases, how different stakeholders can use and benefit from the Resource Description concept.

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Keywords: Resource Description; Production System Design; Value Proposition

1. Introduction

The requirements for production systems are continuously shifting towards higher flexibility and adaptivity. This is due to increasing volatility in the global and local economies, shortening innovation and product life cycles, and dramatically increasing number of product variants. The realization of these requirements calls for new solutions that would drastically reduce the time and effort put into planning and implementing the alterations in a factory and to design new production systems [1]. There is a desire for support these design and planning activities by computerized solutions. In order to do that, information from both the products and production resources need to be available in a computer-interpretable format.

Number of stakeholders, such as resource providers, system integrators, system end users, operators and maintenance personnel, are involved in different phases of the production system lifecycle. These phases include for instance design, procurement, installation, deployment, operation, reconfiguration and maintenance. A resource provider produces and supplies production devices. A system integrator designs and integrates these devices into a production system based on the requirements of the product manufacturer, and installs and deploys the production system into operation. When the system is operational, the employees of the product manufacturer operate the system and the maintenance personnel perform the needed maintenance operations to keep the system running. Finally, when the system does not anymore respond to the product requirements, it is reconfigured or scrapped, and some of the resources may be sold to other companies. Common for all of these stakeholders and aforementioned processes is that they would benefit from inclusive and detailed information about the production resources, which is provided in a standard and computer-readable format.

Some attempts have been taken to provide formalization to resource descriptions. For instance AutomationML, which is optimised for production system level information exchange, has been used to represent manufacturing resources as 'mechatronical units' in [2] and 'SmartComponents' in [3]. In both cases the detailed resource data model is not shared directly into use for other tools, but it is hidden behind the API. We have developed an XML-based Resource Description concept to formally describe production resources. It has been described in details in our earlier works, e.g. [4,5].

The objective of this paper is to analyse the needs of different stakeholders in the domain of production automation, and how the Resource Description concept, and the associated software tools, can be utilised to bring value for these stakeholders. Value Proposition Canvas [6] and Use Case Analysis [7] are used as methods for this research.

The paper is organized as follows: Section two provides a short introduction to the Resource Description concept. Next a Value Proposition Canvas method is introduced, and notations used in the following illustrations are opened. In fourth section, we identify the different stakeholders and present Value Propositions for each of them. In addition, the selected use cases are presented to demonstrate the use of the proposed Resource Description concept. Finally, we end with discussion and con-

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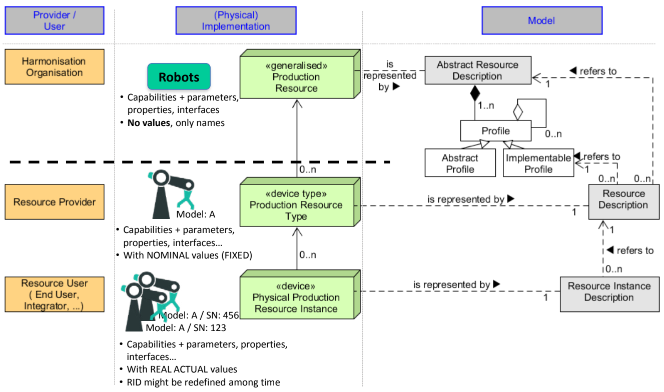

Fig. 1. Resource Description concept and relations between different descriptions.

clusion.

2. Resource description concept

The Resource Description concept provides a comprehensive XML-based digital representation of a technical entity – a production resource. It integrates together information related to functional, geometrical, mechanical, communication, and control aspects. It allows giving a description of resources' functionality including capabilities; interfaces to other resources; parameters related to business, environment and technical characteristics; life cycle related information; and control interface through executable capabilities. [4,5]

The main benefit from Resource Description concept comes from the open exchange of resource data between different parties and tools, with a standardised data model. The descriptions can be collected into (open) catalogues from where the resource data is made available for use to different stakeholders.

The Resource Description concept is a roof term and encapsulates three detailed parts of descriptions: Abstract Resource Description (ARD), Resource Description (RD), and Resource Instance Description (RID), and their interrelations. Fig. 1 describes the relation between these three main parts of the RD concept, and how they connect to a physical world.

ARD is an abstraction and a reference model for production resources. It forms an abstract digital specification and generalisation for a collection of similar kind of production resources (e.g. grippers, feeders, glue dispensers, welding torches). An ARD can be utilised to create an RD Skeleton, a customised RD template, on which a new resource's information can be filled in.

RD is a digital representation of a real, physical production resource. It is the main description in this data model as it describes the details associated to a specific type of hardware resource. The description is common to all same kind of resources i.e. resources having the same vendor, model, type and version. The information content of the description ranges from a capability to Computer Aided Design (CAD) and kinematics models, and from physical interfaces to control interface and functions of the resource.

Through the standardised model the production resources can be formally defined and described. Not only the RD model is standardised, but also some sections of the internal information is standardised. For instance, the capabilities and their parameters are defined and shall be retrieved from an externally provided OWL-based Capability Model ontology. Then the capability information is linked and values stored into an RD. We discuss the Capability Model and how these two concepts come together in [8]. Furthermore, the interface standards can be harmonised through the external services, which provide search features across an interface database. Both of these aforementioned external sources and use of ARDs aim to provide standardisation across the RDs coming from different vendors.

RID is a digital representation of an individual physical instance of a resource. It appends the RD with information that cannot be generalised over all instances of the same resource type, but is specific to one instance only. It carries the resources' current state and historical data events – it is an accumulating information storage.

An Executable Capability concept is a part of the RD, and it defines the (abstract) control interface of a resource in an inclusive, formal, and vendor neutral data model. It describes the actions or operations, which can be executed on the production resource. Examples of Executable Capabilities are "moveToAbsolutePosition" or "stopMovement" for a manipulator resource and "graspExternal" or "release" for a gripper resource. Each Executable Capability contains individual set of parameters, which characterise and parametrise the requested action. The control system finally uses these parameters during the execution of an action on the resource. We discuss the Executable Capability concept more in details in [9].

There are a few software applications associated to the Resource Description concept. One is a graphical editor used to view and edit the RDs. Another one is a Resource Description Catalogue, which offers an on-line platform and database to store and distribute the ARDs and RDs. In addition, it provides simple search and data processing services, and a web service interface for application integration. Third is a Capability Matchmaking software, which matches the product requirements against the resource capabilities, and can be used to look for alternative resources and resource combinations from the resource catalogues [10].

3. Method

We defined the value propositions by following the Value Proposition Canvas method by Osterwalder et al.[6]. First, the different stakeholders were identified. Second, we created customer profile for each stakeholder by analysing and identifying their jobs, pains, and gains. Third, we listed our products and services, and identified how they can provide value for the customer through pain relievers and gain creators. Finally, we found the fit between value map offerings and customer profile needs.

The identification of stakeholders and analysis of their pains and gains were based on our earlier research in projects EUPASS [11] and ReCaM [12]. The information was enriched by several discussions with resource providers, system integrators, and end users, and information collected from literature.

In the following figures of Value Proposition Canvases, customer's jobs are marked with yellow boxes at right. Furthermore, the customer's pains are marked with red boxes and the gains with green ones. At left side, in the value map, our products are shown as yellow boxes. The green boxes in the value

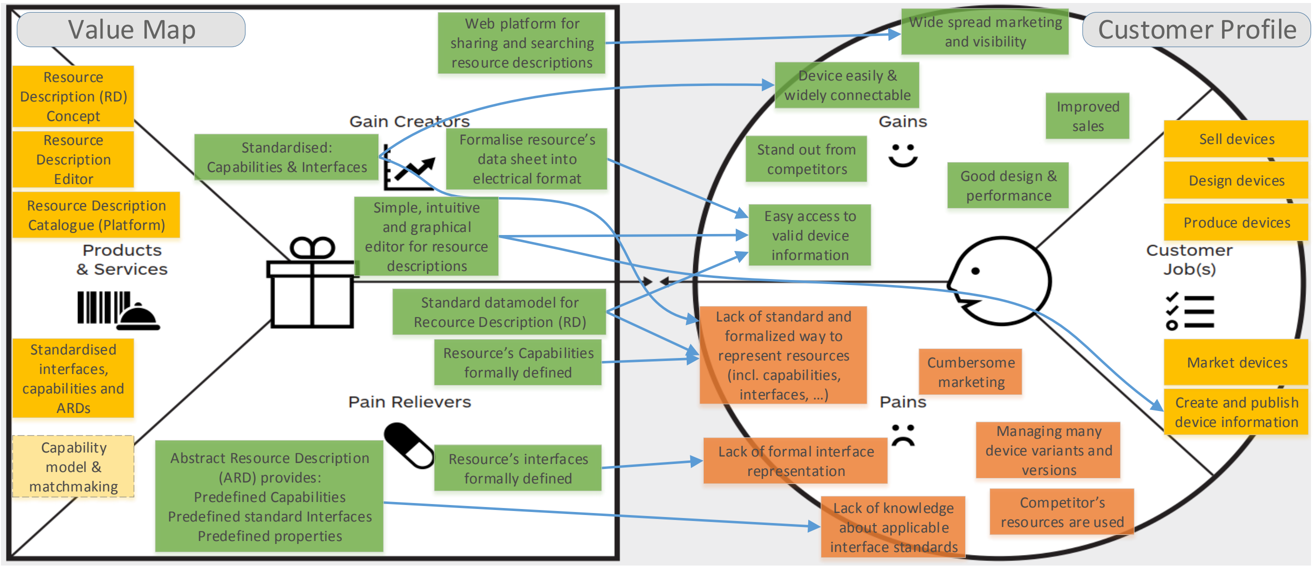

Fig. 2. Value Proposition Canvas for a resource provider. Template from [13]

map denote features and offerings of our concepts, products, and services. The dashed boxes denote products or value offerings, which are external to the Resource Description concept, but closely related with it. These external products or offerings provide an essential value for specific customer pains or gains, therefore these are also shown in the value propositions. Different arrow colours are used for clarity.

We opened our value propositions through use case scenarios, which detail a specific aspect of the defined value proposition.

4. Value propositions and use cases

We identified and selected the following stakeholders for our analysis: resource provider, system integrator, and product manufacturer. The product manufacturer acts as an end user of the resources and the system. While reading the Value Proposition Canvases one has to consider that the same actor may have multiple different stakeholder roles. For example, if the system end user company does also the system design, it has also the system integrator role. We identified a few more stakeholders, such as the resource owner and standardisation organisation. The resource owner is often the same actor as the end user. Because the focus of this paper is on how the RD concept can support system design and reconfiguration, the resource owner will not be further considered here. The RD data model and associated products and services offered in the presented value propositions actually show the viewpoint of a standardisation organisation, and thus it is connected into the left side of all presented value propositions. The selected stakeholders are discussed in the following sub-sections.

4.1. Resource provider

Fig. 2 shows the Value Proposition Canvas for the resource provider as a customer. The primary job of the resource provider is to design, produce, and sell production resources to the product manufacturers. In addition, they need to market their resources and create descriptions, data sheets, and illustrations supporting the previous activities. The detailed information about the resource is also needed during the system design and use of the resource.

Issues for resource provider are manifold. How to get good visibility for their resources and how to compete with competitors? How to make the resources widely known and used in different customer applications? These relate to integrability and interoperability of the resources, information exchange, and also to marketing.

Ease of integration originates from interface standards. There is a lack of knowledge about applicable interface standards. Sometimes there are many competing standards, and to know the available options for a specific case is difficult for resource providers. Occasionally, publicly available standard does not exist, and new specification need to be defined. Nevertheless, a systematic and formalised presentation of interface standards with their selective features is missing. Likewise, there is no formal way to express the capabilities of the resource. In summary, there is no standard way to represent the comprehensive characteristics of the resource in a formal and comparable manner.

Resource providers would benefit from an approach, data model, and tools, which would allow them to describe their offerings, i.e. resources, in a common format, and to make these descriptions easily accessible by potential customers, i.e. system integrators and end users. Additionally, resource provider would gain from good design and performance of their product, which makes them stand out from their competitors. All this would lead to improved sales and a well-known position in the markets.

Our value proposition aims to solve a few of these pains and gains by 1) an Abstract Resource Description concept, supporting the design process of a new resource and 2) an RD providing formalised and comprehensive description of a resource.

4.1.1. Design and produce a new resource

The ARD is higher level model of resources compared to the RD. Through Profiles the ARD defines sets of characteristics, which helps to design and produce more uniform re-

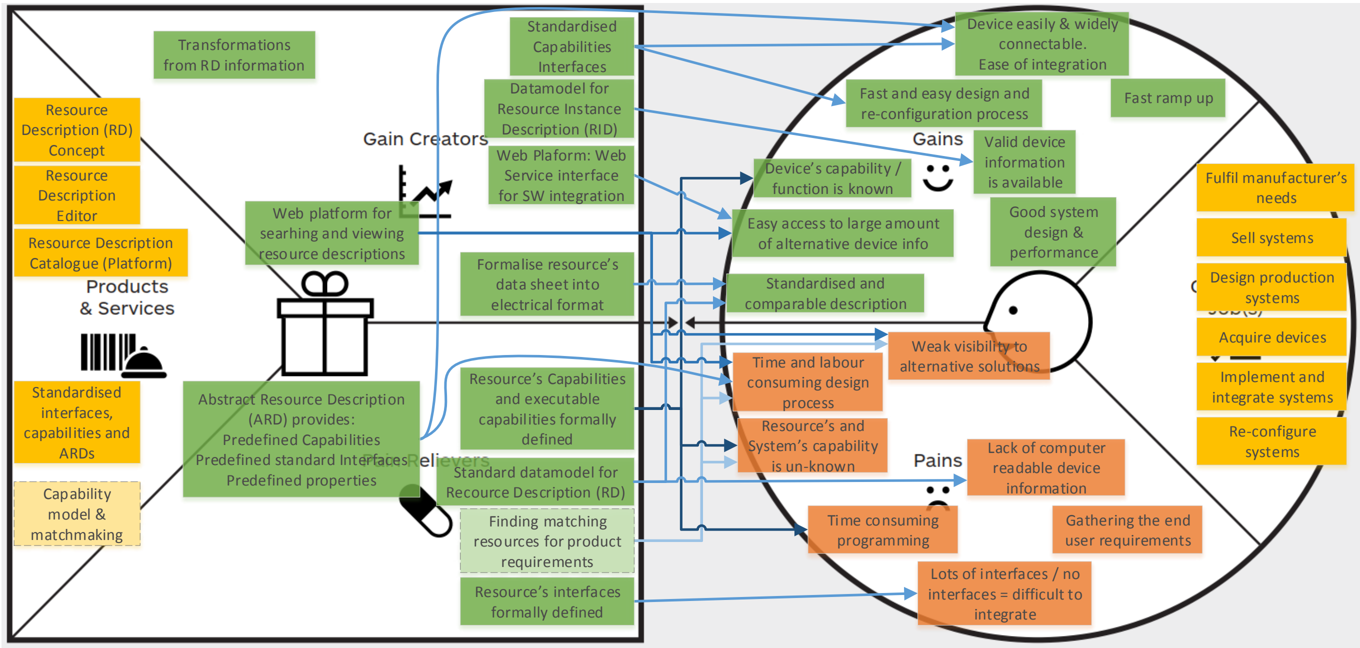

Fig. 3. Value Proposition Canvas for a system integrator. Template from [13]

sources from function and interface point of view, increasing the chances to connect the resource with other ones, even coming from other vendors. The ARD concept supports a new resource generation in two ways. First, it provides a set of design limitations and prerequisites. The resource provider gets a predefined set of features, which define a bare minimum of capabilities, interfaces and other requirements for a new resource. Second, it can be used to create a customised RD template, an RD Skeleton, on which the resource provider can fill in the resource information.

4.1.2. *Make and publish a resource description*

Resource provider can take the RD data model and define their resources directly using the core model. However, more efficient and easier way is to use an RD editor to fill in, edit, and view the resource information. This tool helps the resource provider by offering interconnections to the associated data models and external data sources. It also aids to keep the RD data coherent including the internal links. Output of the RD editor is an RD file.

Finally, the RD needs to be published on the market, and made available for the end users to acquire it. Our tool, Resource Description Catalogue Platform, supports this. After uploading the description to the catalogue, the various customers using the catalogue service can search and compare the RDs from different resource providers. The catalogue users can download the RDs information to their engineering tools used for system design, commission or execution, or any other yet unforeseen use. For example, formal descriptions from public catalogue can be used in automatic capability matchmaking, which will increase the possibility to get new customers using the resource.

4.2. *System integrator*

Fig. 3 shows the Value Proposition Canvas for the system integrator as a customer. Their main job is to serve the manufacturer's needs by designing, implementing, and integrating production systems. Their job can also include acquiring devices and re-configuring the existing systems.

They suffer from a time consuming and labour intensive system design process. One big issue is the lack of computer readable device information. Weak visibility to alternative resources reduces opportunities for new solutions, which could be more efficient, adaptable, or suitable for the case. It takes a lot of time to go through scattered information about alternative resources. This is because the vendor catalogues are not relying on formal and standardized description, which makes it hard to compare different resources, especially by automatic means. The resource's and system's exact capability remains unknown for the integrator or at least finding it out requires considerable effort for them. System integration is also difficult and time consuming as the interfaces are not compatible or even standardised, and thus customised adapters are needed. Sometimes there are too many competing interfaces available at the resources' side, and selecting right interface/resource combinations so that the whole production system can be integrated all together gets difficult. Furthermore, the programming of the system takes a lot of time and effort.

System integrator sells their services to the manufacturing companies. Thus many of their gains originates from being able to provide high-quality and efficient service to their customer. Therefore, the end-customer's gains become also their gains. System integrator would gain from fast and easy system design, integration, and re-configuration processes. The system ramp up should be smooth and fast. Production system needs to operate efficiently and at high performance. Similarly, system integrators are interested to have a large resource pool to search from with commensurate resource information. All previously listed processes would benefit from valid and up-to-date resource information.

4.2.1. Design a production system

The key question for system integrator is to find efficiently the connectable resources, which can perform the requested production task with appropriate quality and capacity. Another objective could be minimising the system re-configuration and maximising the existing resource utilisation in case of product switch over. Here the RD concept and other tools in our value proposition come into picture.

In past, one difficulty for the re-use of resources has been that resource's characteristics are unknown. The RD improves the re-use of resources and keeps them more viable, because RD carries accurate information about resources capability and interfaces, and offers it in standardised and easily accessible format.

The Resource Description Catalogue Platform offers the system integrator an easy access to vast amount of resources with commensurate values. There can be different catalogues available for their use. A specific end user can have their local catalogue with resources in their possession. This catalogue can be further divided into collections representing a production line or resources currently at the storage. Likewise, there can be global catalogues representing an on-line market place for production resources, or a smaller catalogue for providing offerings of a specific resource provider. Nevertheless, the most important is that these all share the same RD data model and that the data from multiple catalogues can be easily combined for an integrated search.

Different engineering tools access the pool(s) of information the resource catalogues provide, and utilise either the full RD information or focus only on specific part of the description. For example, the full description with all the details can be offered for the user in human readable format. A production system engineering application can look for performance metrics or capability information of a resource and optimise production system accordingly. An electrical engineering application can calculate the required energy supply for the system and ensure that energy pass through capacity of each resource is not exceeded. A system visualisation application can access the CAD or kinematics model information of a resource through an RD.

One such engineering tool is the capability matchmaking application [10,14]. The system integrator can use the matchmaking to find out which resources or resource combinations can perform specific production processes. This will reduce the time needed for system design as the tool can propose possible resource combinations, out of large search space. Possible in this context means that processes and process parameters match between a product requirement and resource capabilities, and that interfaces match between the connected resources. Our assumption is that matchmaking can propose unforeseen and emerging combinations, which can lead to improved and more optimised system configuration.

4.2.2. Integrate a production system

The resource provider can define installation and integration instructions and limitations in the RD. Similarly, they can provide calibration procedures for a resource. Then, system integrator can utilise these information when assembling and integrating the resource into a production system.

The system integrator can utilise Executable Capability concept while making the task programming for the production system. In the future this can be even (semi-)automatic task. Executable Capabilities expose the control interface of each resource in an unified description format, even the resources would come from different vendors and follow different control architectures and protocols. In order to integrate a system, interconnected resources must share the same architecture and at least one common protocol. The application used to orchestrate operations of the production system can utilise provided information for accessing and calling actions at the resources of the production system. Implementation of the control system is not limited by the RD concept. A resource provider can choose to support either central or distributed architecture(s), or even both, and several (communication) protocols.

4.2.3. Invitation for tender of an ideal resource

One special application of RD for system integrators is to use it as a vessel for an invitation for tenders. System integrators can create a new RD file same way like resource provider does for existing resources. In contrast, they can specify an ideal resource in terms of the RD, and send it to selected resource providers. In the future, the Resource Description Catalogue Platform could have a specific market place for such invitations for tenders.

4.3. Product manufacturer (end user)

Fig. 4 shows the Value Proposition Canvas for the product manufacturer (i.e. end user) as a customer. Their main job is to produce products with the production system. They are interested in satisfying their customers by producing high quality products with high delivery reliability. Internally they are interested on making this as efficiently as possible, e.g. by maximizing the resource utilization. Depending on the nature of the product and production, the production system can be either adjusted or re-configured for a new product every now and then.

The main pains of a product manufacturer are how to respond to the changing production demands and product requirements with the manufacturing system. They suffer from slow product change-over, slow system set-up, and slow reconfiguration, when multiple products are produced with the same system, either in parallel or in sequence. They are concerned about resources becoming obsolete, and not usable for production any more. This might be the case if re-configuration of the system is impossible. Contrary, they will benefit from efficient production, good system design and performance, reuse of devices, and fast ramp up. Fast and easy re-configuration and system set up will bring them gain towards competition.

Possibility for re-use of the resources is an important aspect. Valid and up-to-date resource information provides foundation for accurate decision making, e.g. when deciding about the reconfiguration of the system and re-use of the resources. The manufacturer is not only interested about the nominal capability and values of a resource, but they are more interested about the current capability and updated characteristics of the resource. This is because resources wear and tend to drift during the use. They might have been upgraded, or calibration results some changes. The resource's nominal values are available from the RD, and an RID is designed for storing and exchanging the resource instance related information. This includes updated and historical data.

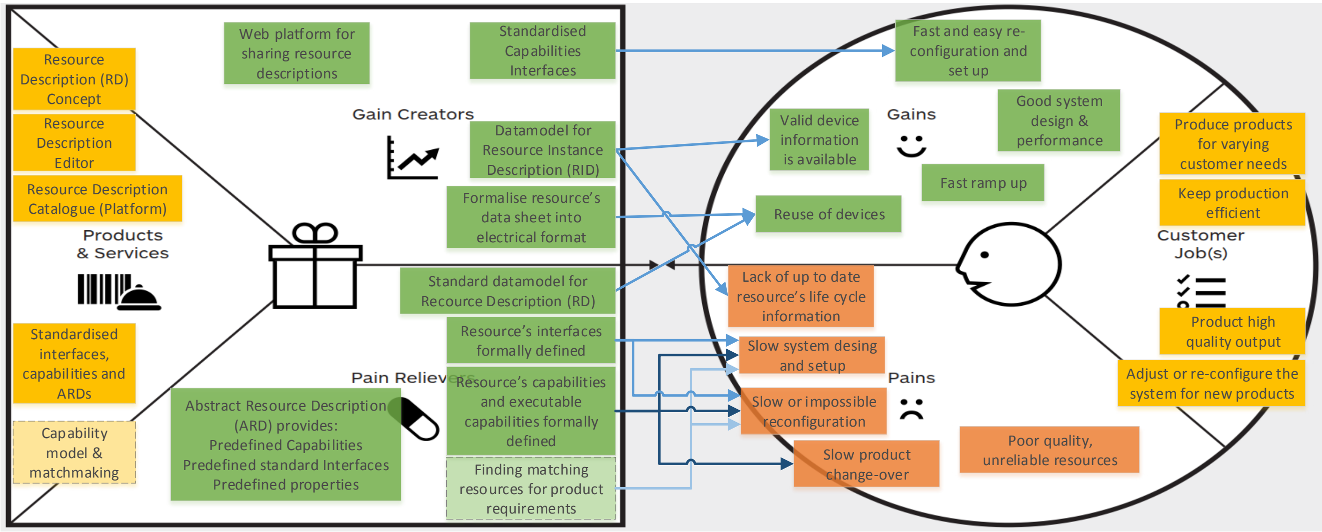

Fig. 4. Value Proposition Canvas for a product manufacturer. Template from [13]

5. Discussion and conclusions

We discussed the value proposition of an XML-based Resource Description concept from the point of view of three customers: resource provider, system integrator, and product manufacturer (i.e. end user). Value Proposition Canvases were used to illustrate the pains and gains of these different stakeholders, and to map them with the pain relievers and gain creators provided by the Resource Description concept and associated software tools. In fact, the presented value propositions can be seen as the value propositions of a standardisation organisation towards the production automation domain, as they should be finally the promoter of such standardised resource descriptions.

The main beneficiary of the RD concept is the system integrator. The formalized description of the manufacturing resources enables automatic search, filtering, manipulation, and decision making upon the published information. Various tools utilized in system design, integration, and commissioning can take advantage of this information, making these processes more efficient. The main benefits for the resource provider are wider visibility to their offerings through global resource catalogues, and better integrability of the resources with the resources of other vendors. The product manufacturer will benefit from faster system design, reconfiguration and ramp up. Furthermore, the collection of life-cycle information allows better insights to support maintenance, re-configuration and re-use decisions.

In order to realize the discussed benefits, the RD concept needs to be widely adopted by the resource providers. They need to publish much more information, in a specific RD format, about their resources than what they have accustomed. This might be a considerable challenge for the acceptability of the proposed concept among them.

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