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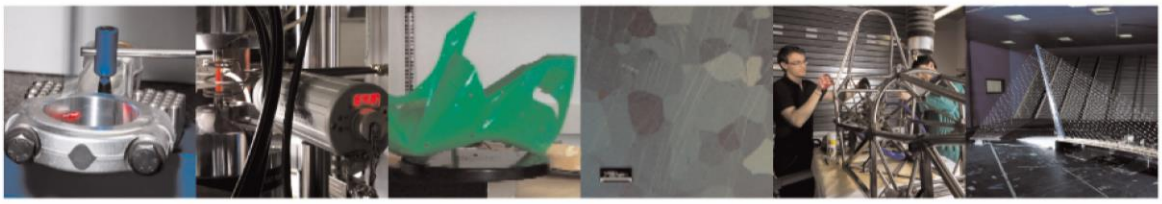

Innovative flexibility-oriented business models and system configuration approaches: An industrial application

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Innovativeflexibility-orientedbusinessmodelsandsystem configurationapproaches:Anindustrialapplication

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Introduction

The reduction of products lifecycle, due to accelerated technological trends or to very fast market dynamics generated by modern consumption uses, can be the cause of frequent changes in the characteristics of the products and their production volumes. A fundamental key success factor, especially for manufacturers operating in sectors where turbulence is high, is the capacity to rapidly follow unexpected market fluctuations in order to keep customers satisfied and to acquire the reputation of reliable suppliers. However, to reach these goals, they must rely on manufacturing technologies with the right flexibility or re-configurability level to cope with such rapid changes in volumes and features of the produced parts. Thus, the decision on the level of flexibility [3,19] and re-configurability of manufacturing systems is a key decision which can strongly affect company competitiveness. Typically, flexible manufacturing systems – systems that have the embedded potential to adapt to external changes – are expensive and less performing in case of volume productions, while reconfigurable manufacturing systems [9] – systems that have the enablers to be easily modified to adapt to external changes – present a lower initial investment cost but may require additional cost (and time) to be reconfigured, which could be not compatible with market requests [23,24]. level of manufacturing systems is rather complex, industrial companies often opt for production systems embedding a very high level of flexibility that guarantees the capability to satisfy a wide range of future unexpected requirements. In this way, however, they make a sub-optimal choice, since they pay for something that probably will not be used and experience lower manufacturing performance in the medium term.

To solve the dilemma and increase manufacturing competitiveness, researchers recently proposed new service-oriented value propositions that equipment suppliers can offer with the aim for optimizing the manufacturing flexibility of their customers [4,11]. However, these business models imply a risk shift from the customers to the suppliers, hence, it is essential for suppliers to acquire a better awareness of the manufacturing flexibility embedded in the systems they offer as well as of the production performance and costs under the logic of "Total Cost of Ownership". In support to this statement, the capability to estimate the economic performance of these business models is outlined in the literature as a critical success factor for their successful implementation [5,12]. In fact, very few methods and tools are available to jointly address the configuration of a production system, the underlying business model and a financial assessment, specifically tailored to the machine tool sector

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[6]. Moreover, the available approaches usually rely on principles and criteria (such as discounted cash flow techniques) that are appropriate for static markets in which uncertainty and turbulence do not play a major role. Thus, methods able to optimize the manufacturing flexibility and estimate the economic impacts in high-uncertainty contexts become fundamental enablers to support the viability of new flexibility-oriented business models.

To cope with uncertainty, stochastic methods for production planning and manufacturing system configuration have been proposed in the last years [20,21]. These latter suggest the type and number of machines to include in the system layout in order to cope with the expected variability optimizing a stochastic cost function, typically the expected value. These methods entail system configurations that are often labeled as "focused-flexibility manufacturing systems", i.e., systems with the minimal flexibility level needed for the considered production scenarios [17,18]. They were proposed by the manufacturing research community with the purpose of technically configuring production systems, but they were not related until now to the business model research. In this paper we aim at demonstrating that "focused-flexibility" configuration approaches provide a significant support to the use of innovative business models in the machine tool sector and might help to push their adoption.

The outline of the paper is as follows. In second section, innovative flexibility-oriented business models are presented. In third section, stochastic configuration methods are discussed as potential enablers for the presented business models. In fourth section, an industrial case study is elaborated, showing the concrete potential of stochastic configuration methods. Finally, in fifth section, limitations and future research directions are outlined.

Innovative business models for focused-flexibility manufacturing systems

A business model addresses how a company produces value for the market and how it remunerates its stakeholders. It describes the main pillars of a company structure. i.e., the value proposition, the supply chain configuration and the revenue model [2,7]. A business model represents an intermediate approach to substantiate the company's vision and mission into detailed business processes and manufacturing technologies [15].

Recent literature emphasized the role of business model innovation in the machine tool industry with the aim at increasing the competitiveness of both system suppliers and end-users. Different taxonomies and typologies of innovative business models were proposed. In 2002 Molinari et al. [13] presented a categorization of new business models based on different factors: the "Ownership of equipment", the "Location of production", the "Responsibility for the operation of the equipment" and the "Responsibility for the maintenance of the equipment". In 2003, Lay et al. [10] added two additional categorization dimensions for classifying and designing new business models: the "mode of payment" and the "number of customers". In 2004 Tukker [22] classified the value proposition of service-oriented business models distinguishing between product-oriented Product Service Systems (PSS), use-oriented PSS and result-oriented PSS. In order to define customized and more detailed business models for the machine tool industry, Copani et al. [7] proposed a set of potentially interesting business models: "Build – operate at customer plant – own", "Full operation concept", "Equipment supplier turns into a part supplier", "Supply park concept", "Own and operate at customer plant with final purchase option", "Multi-ownership for big and complex investments". Biege et al. [2] made an effort to summarize new business models for the machine tool sector referring to Tukker's scheme: "Availability guarantee", "Solving customer qualification deficits", "Reconfigurable production systems" and "Lean machine business concepts" under product-oriented PSS; "Leveling irregular and temporary customer capacity requirement" under use-oriented PSS; "Production service" under result-oriented PSS.

Recently, a new type of innovative business models specifically oriented to manufacturing flexibility optimization were presented as a completion to the wide list above discussed and consolidated in literature [4]. They were finalized grounding on a case study analysis investigating both the effective needs and the most relevant opportunities in the machine tool sector. The case study analysis involved a supplier of production systems, (system integrator), a supplier of machine tool components, a service engineering company and a manufacturing end-user in Italy. After the analysis a reduced set of innovative business models were selected and contrasted together with machine tool builders and system suppliers in order to verify their applicability and industrial interest. Finally two innovative business models were selected as the most promising: the "reconfiguration guarantee" and the "capacity guarantee".

Reconfiguration guarantee business model

In this business model, the system supplier designs the flexibility level of the production system grounding on a set of future scenarios modeling the forecasted customer's needs, without considering the need of extra-flexibility whose future utilization is uncertain. On the contrary, through the use of focused-flexibility design approaches, the system supplier is able to identify possible future reconfiguration actions that might be necessary to cope with the future demand scenarios considered.

Under the frame of the reconfiguration guarantee business model, the contract between the supplier and the end-user covers the supply and installation of the production system as well as the economical conditions that might regulate the possible future reconfigurations taken into consideration, if they will be requested by the customer. Hence, the contractual variables under negotiation are price of the initial production system configuration and the price for a set of possible future reconfigurations.

The role of the customer and the supplier in the frame of this business model, during the whole lifecycle of the system, is represented in Fig. 1 (where DEMAT is the acronym of the FP7 EU Project entitled "Dematerialised Manufacturing Systems: a new way to design, build, use and sell European Machine Tools" and DMS stands for "Dematerialised Manufacturing Systems").

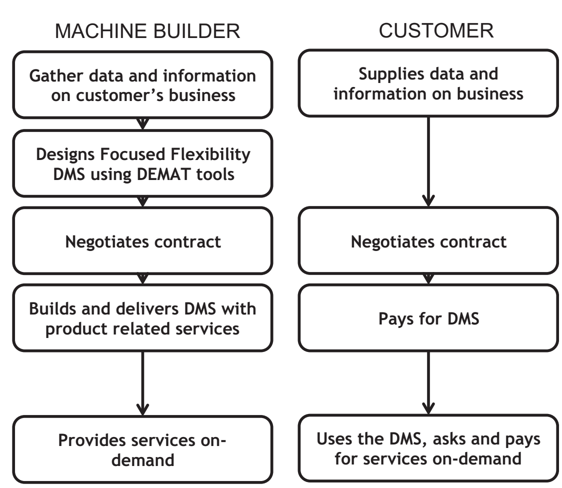

Fig. 1. Role of customer and supplier in "reconfiguration guarantee" business model.

In this business model, the system supplier would provide its customers machines with a limited level of flexibility but with higher re-configurability. Consequently, he renounces to higher initial incomes in sight of future uncertain cash flows, whose occurrence depends on the future evolution of the market as well as on the will of the customer to ask for a reconfiguration. Thus, from a financial point of view, this business model might appear less attractive for the supplier compared with the current practice.

However, the key factor for the viability of this business model relies on the favor of the customers to it. If customers recognize the advantage of this innovative value proposition, supplier's turnover will grow thanks to the acquisition of new customers. In addition, suppliers will have the possibility of establishing long-term relationships with their customers, entailing a better understanding of market needs and a privileged position to promptly address them. However, depending on the market response and on his commercial and financial strategy, the supplier might decide to ask his customers a margin premium for the focusing-flexibility service he offers as well as for the related advantage for the customers. This advantage will consist in a limited initial investment in extra-flexibility, whose utilization might be very uncertain, and in postponing future reconfiguration costs when and only if they will be effectively necessary.

On the other hand, compared to the immediate availability of extra-flexibility, in case of serious demand turbulence, the reconfiguration service might take some time and could affect the responsiveness of the customer to rapid market changes.

Finally, from a business model innovation point of view, this scenario can be considered innovative because the supplier pushes himself toward a more customer-centered approach, accepting a cash-flow risk in favor of an advantage for his customers and a closest relationship with them.

Capacity guarantee business model

In this business model, the system supplier always guarantees his customers a production solution with the needed production capacity and technology. Under this frame, the supplier keeps the ownership of the production system, is in charge of maintaining it, reconfiguring it when needed and, finally, he is responsible for machines dismantling. The customer does not have to take care of machinery ownership, maintenance and update over time, he simply buys the production capacity he effectively needs and uses it. Thus, the "Total Cost of Ownership" is fully sustained by the system supplier. However, the parties have to agree on a minimum and maximum contractual range of capacity at the beginning of the relationship. Hence, the user is constrained to pay a minimum capacity per time period, even if he does not effectively need it, while the supplier guarantees the capability of the system up to a maximum value.

In addition, the supplier may offer his customer a buy-option, in order to allow him to postpone the investment decision when the uncertainty will be lower. Under this business model, important contractual variables will be the price per capacity use, the penalties that the supplier has to pay if the requested capacity cannot be provided and the capacity range the contract guarantees for. The role of the customer and the supplier during the whole lifecycle is represented in Fig. 2.

In this business model, the supplier will completely undertake the system lifecycle management responsibility, including reconfigurations, guaranteeing his customers the adequate production capacity they will ask for within the duration of the contract. The supplier has to be proactive in monitoring the demand variation in order to decide the needed reconfigurations to put in place, thus needing proper system design methods to trigger the right reconfiguration steps.

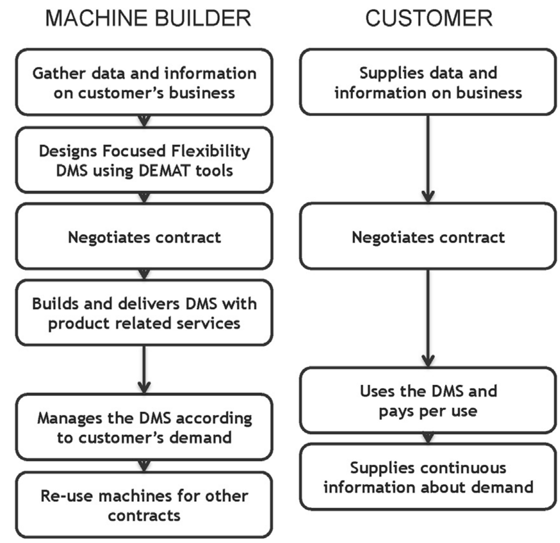

Fig. 2. Role of customer and supplier in "capacity guarantee" business model.

Within the framework of this business model, the change of role for the system supplier is significant. He has to turn his business from system provision to system management. Also the financial and logistic implications are considerable, it will be necessary to rely on a wide stock of machine tools of different types, as this is suggested as a good way to maximize the reconfigurability strategy performance [14]. These machine tools will be installed at the customers' premises, but also moved from a customer's plant to another, in order to implement proper reconfiguration actions and to support the production capacity agreements coming from new contracts. Hence, an important success factor for suppliers will be the ability to optimize the allocation of the available machine tools to the customers and to maximize their utilization.

Under the adoption of this business model, suppliers are expected to gain a marketing advantage, since the possibility of simply buying a capacity guarantee service would attract new customers, and because of the long-lasting relationship between customers and suppliers. In addition to marketing benefits, the increased risk undertaken by the suppliers will be compensated by higher profit margins due to the necessarily higher price per capacity use.

From the customers' point of view, the advantage will come from the possibility of being completely focused on their core business, without the need of managing the setup and management of the production equipment, which is totally under the responsibility of the supplier. However, customers will lose competences in production systems design and management on one side, and will face a higher risk of production losses in case of a default of the supplier or if he cannot provide the needed capacity at the right time.

To some extent, this business model can be considered more innovative than the previous one, since the supplier undertakes direct responsibility in managing a production system for his customer to guarantee manufacturing results. The revenues of the supplier are linked to the results (the guarantee of providing the right production capacity), known in the literature as "performance-based contracting" [8].

In a dynamic perspective, the second business model can be considered an evolution of the "reconfiguration guarantee" business model. Since it implies higher risks and a deeper transformation of the traditional business of machine tool companies, it is reasonable that companies start acquiring the competences for designing and managing manufacturing flexibility first, thus acquiring the competences for the adoption of the "reconfiguration guarantee" business model. In fact, the first one implies a new way of selling production systems but, at the same time, it does not revolution the traditional business.

Focused-flexibility design methods to support innovative business models

An essential condition for the viability of the described business models is that both the supplier and the customer agree on what the contract will cover and to what extent. The machine tool builder cannot guarantee for the whole range of unexpected market conditions without the need of asking extremely high fees to accept the associated risk.

At the same time, a key factor for his success is the capacity to accurately design a system in terms of the optimal level of flexibility needed and the possible future reconfigurations.

From the other side, the customer needs to figure out possible realistic future scenarios to benefit from the right system configurations and, thus, being able to quickly take advantage of favorable market conditions.

For this reason, the definition of the set of scenarios modeling the market evolution, together with the availability of system design methods able to take into consideration the scenarios and provide an advice for future reconfigurations are necessary rather than simply advisable. In fact, the definition of future reconfigurations, a reliable estimation of their cost and, consequently, the definition of proper contractual clauses (i.e. prices, penalties, capacity ranges, etc.) are the necessary prerequisites for the negotiation of contracts within the described business models [5].

To this aim, design methodologies for focused-flexibility systems, based on scenario modeling and stochastic programming, are the ideal candidates to address these needs [1,16,20].

These approaches address the uncertainty affecting the problem grounding on the definition of a scenario tree to model the possible evolution of the production problem in the future. An example of a scenario tree is represented in Fig. 3 where the solid nodes represent the evolution of the production needs (products to be manufactured, demand, etc.) over time.

The root node of the tree represents the initial production problem to be addressed. From this node, two branches depart toward the leaves of the tree, modeling the different evolutions of production problem in the second stage. The same applies moving from stage 2 to stage 3. The path from the root node to a leaf represents a scenario. Each node in the scenario tree is labeled with its occurrence probability starting from the father node. The occurrence probability of a scenario (a leaf in the tree) is calculated multiplying the occurrence probability of all the branches toward the leaf itself. In order to provide consistency to the scenario tree,

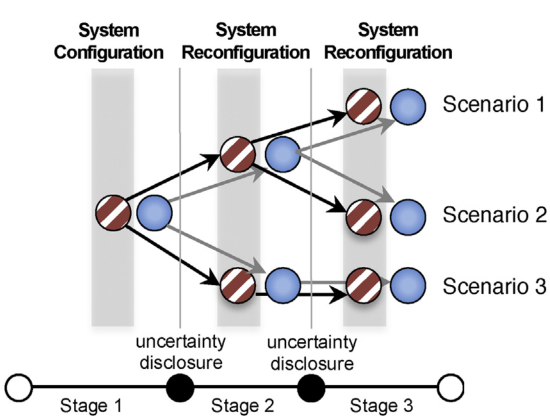

Fig. 3. Multi-stage stochastic programming framework.

the sum of the occurrence probability for all the scenarios must be equal to 1.

The scenario tree serves as a support to design a production system and its evolution within the considered time horizon. An initial production system configuration is designed according to the characteristics of the production problem in the root node of the tree. Starting from this configuration, as the production problem changes according to the different scenarios, a different system configuration is defined (Fig. 1, striped bullets), thus describing the reconfiguration steps to be taken.

Multi-stage stochastic programming approaches implement these mechanisms with the aim at optimizing the expected value of a given objective function (e.g., the expected value of the investment and operative cost) over all the scenarios in the tree.

To this aim, the decision horizon is partitioned into periods, named *stages*. Each stage is associated to a set of variables whose value must be decided without having certain knowledge of what is going to happen in the future but only considering the stochastic information embedded in the scenario tree.

In the application of multi-stage stochastic programming approaches to the configuration of a production system, *first-stage variables* define the initial configuration of the system targeted to the current production requirements (the root of the tree).

The following stages are associated to a set of stage variables used to react to the evolution of the production requirements. In Fig. 3, *second-* and *third-stage variables* define a first and a second reconfiguration step to target the evolution of the production requirements. In particular, a specific reconfigured production system (striped bullets) is defined to target a specific set of production requirements (solid bullets on the immediate right).

Given a set of scenarios $\omega_i \in \Omega$, the multi-stage stochastic programming approach looks for the values of all the stages variables aiming at optimizing the objective function:

C_{INV} is the initial investment cost, $C_{OPs}(\omega_i)$ is the operational cost at stage s in scenario ω_i; $C_{RECs}(\omega_i)$ is the reconfiguration cost at stage s in scenario ω_i; r is the discount rate used for cost actualization and E_Ω operator calculates the expected value over all the possible scenarios ω in Ω.

The minimization of the considered objective function:

$$\min C_{INV} + E_\Omega \left[\min \sum_{s \in Stages} \frac{C_{REC_s}(\omega_i) + C_{OP_s}(\omega_i)}{(1+r)^{s-1}} \right]$$

returns the optimal system configuration together with the planned future reconfigurations associated to each node in the scenario tree.

The application of the described configuration methodology provides important information that can be exploited to assess the viability and the conditions for a possible contract within the proposed business models.

When considering the *reconfiguration guarantee business model*, the system provider asks its customer an initial fee F_0 and further fees F_s at each reconfiguration of the system. Since the system provider is not going to share the operation cost C_{OP} with the customer, C_{INV} and C_{REC} represents the cost he must undergo to provide the equipment to the customer and provide his profit margin. In fact, the supplier's profit is the difference between the fee F_i and the costs he has to incur for the initial configuration and the successive re-configurations.

An adequate estimation of these costs provides the system supplier the capability of correctly estimating the fees that must be paid by the customer, thus providing a solid background on the definition of the contract.

On the contrary, when considering the *capacity guarantee business model*, the system provider takes care of the investment, reconfiguration and maintenance costs. Once again, his profit relies

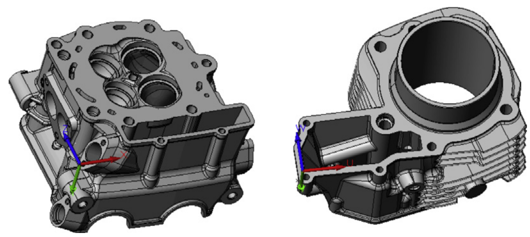

Fig. 4. Product type C and D.

on the difference between the fee asked to the customer and the incurred costs. Also in this case, being able of estimating future reconfigurations and operation costs using a stochastic support allows the definition of negotiation and contractual strategies based on an effective management of the significant risks associated to this business model.

Application to an industrial case

The described system configuration methodology is applied to an industrial case of a company working in the motorcycle sector to compare the performance of two different business models: the traditional one respect to the "reconfiguration guarantee" business model.

Production problem setting

The first step was to model the production problem and build the scenario tree. The production of six different product families was envisaged (A, B, C, D, E, F). One representative product for each family was considered to provide input data for the analysis. Two of the considered product types are shown in Fig. 4.

Scenarios are used to model different types of changes that can affect the considered production problem. In the considered manufacturing problem, the significant influencing factors are:

1. The variability of the demand.
2. The introduction of new products to be manufactured.
3. The changes affecting the products due to customers' requests, influencing the machinability of the parts on certain class of machines (e.g., 4-axes, 5-axes).

These three sources of variability were referred to the different products families, considering their market and technological characteristics. In particular, it was assumed that:

- Product family "A" could undergo a modification that entails the need of using a 5-axes machine for the given pallet configuration.
- The demand for family types "B" and "C" is going to remain stable or to increase.
- Family type "D" is a new product family entering into production. According to how the market reacts to this new product, its demand could be low or high.
- The demand for product family "E" will remain stable within the whole time horizon.
- Product family "F" is at the end of its commercial life and, hence, its production will cease in the near future.

The hypothesized changes affecting the different product families were mixed together in order to build a two-stage scenario tree with a single root node ($\boldsymbol{\omega_0}$) representing the current production problem and eight different scenarios $_{\mathbf{1}}, \ldots, \boldsymbol{\omega_8}$. Each scenario was characterized by the estimated production volumes and an occurrence probability (Table 1).

According to the life cycle time of the considered products families, the scenario tree was built spanning a time horizon of eight years divided into two stages. The first stage, associated to scenario node $\boldsymbol{\omega_0}$ refers to the initial industrial problem, while the second stage, associated to scenario nodes from $\boldsymbol{\omega_1}$ to $\boldsymbol{\omega_8}$, refers to possible future changes that may occur.

Results

The stochastic programming configuration approach described in the previous chapter has been applied to the industrial case under study to compare the traditional business models with the reconfiguration guarantee business model.

In the traditional case, due to the characteristics of the addressed market sector, characterized by high volatility of the demand and the occurrence of frequent changes to the manufactured product, a flexible manufacturing system would be considered the more advisable system architecture. Thus, the customer would require a production system able to tackle the initial production problem as well as the possible forecasted evolutions. To evaluate this option, we applied the configuration approach considering the requests for all the scenarios obtaining the solution reported in Table 2.

It consists of five 4-axes machines, two 5-axes machines, four Load/Unload stations and nineteen pallets allocated to the different product types that, all together, would be able to face the severe changes of the considered scenario. The associated production system cost is € 2,730,000.

On the contrary, under the innovative conditions of the reconfiguration guarantee business model, the supplier would provide a production system able to fulfill just the short term demand, but designed to be re-reconfigured in the future with a small cost, to match the second stage nodes in the scenario tree. To generate an optimal solution, the stochastic programming approach was used with the objective of minimizing the expected value of the supplier's investment in equipment and satisfying the production requirements.

Table 1
Summary of the nodes in the scenario tree.

Scenario nodes	Occ. Prob.	Annual demand						
		A1	A2	B	C	D	E	F
ω_0	1.000	7585	0	60,957	60,957	0	39,633	9541
ω_1	0.336	7585	0	60,957	60,957	11,400	39,633	0
ω_2	0.084	7585	0	67,053	67,053	11,400	39,633	0
ω_3	0.144	0	7585	60,957	60,957	11,400	39,633	0
ω_4	0.036	0	7585	67,053	67,053	11,400	39,633	0
ω_5	0.224	7585	0	60,967	60,957	5000	39,633	0
ω_6	0.056	7585	0	67,053	67,053	5000	39,633	0
ω_7	0.196	0	7585	60,967	60,957	5000	39,633	0
ω_8	0.024	0	7585	67,053	67,053	5000	39,633	0

Table 2
System configuration in the traditional business model.

Cost = € 2,730,000					
Machine tools				LUs	
4-axes		5-axes			
5		2		4	
Pallets					
A	B	C	D	E	F
1	5	6	3	3	1

The solution obtained is reported in Table 3. It consists of an initial system and a set of possible future reconfigurations associated to the scenario nodes.

The column named "Stage 1" reports the system configuration for the initial production problem (the root node of the scenario tree) consisting of five 4-axes machine tools, four Load/Unload stations and sixteen pallets allocated to the different product types with an investment cost of € 1,850,000. The column named "Stage 2" reports the system configurations associated with the different scenarios. For each of them the table reports the number and types of machine tools, the pallet allotted to the product types and the reconfiguration cost. The number of Load/Unload stations remains unchanged and is not reported.

The reconfiguration cost is due to the new equipment that must be acquired and, for the dismissed equipment, a residual value equal to 50% of the initial one has been considered. The cost associated with the second stage is the expected value of the reconfiguration costs weighted by the occurrence probability of the scenarios.

Considerations

The application of the stochastic programming system design methods to the industrial case illustrated in fourth section outlines the potential to support the definition of business models variables under a sustainable customer-supplier perspective.

By incorporating uncertainty in the models they use, they allow the system supplier to design system solutions that optimize manufacturing flexibility and to plan their associated cost over system lifecycle. The capacity to manage flexibility efficiently is a necessary requirement for suppliers offering advanced services for capacity management.

Under the framework of the reconfiguration guarantee business model, the use of focused flexibility design methods provides a system configuration consistently less expensive than in the traditional configuration approaches (in terms of configuration and reconfiguration costs for the supplier). Even without considering the extreme scenarios, the two-stage solution remains the less expensive. Moreover, the configuration and reconfiguration paths for all the scenarios provide the supplier an important support in the definition of the prices for the initial configuration and for the reconfiguration action in the implementation of a reconfiguration guarantee business model. However, it must be noticed that the solution in Table 3 addresses the supplier's point of view, hence, it aims at minimizing the value of the equipment but does not take into consideration the bid for the customer. Hence, the effective convenience for the customer will depend on the pricing policy of the system builder. Under the framework of the reconfiguration guarantee business model, the latter might decide to charge higher profits on the future reconfigurations and to make the initial system sales more attractive with the aim at acquiring new customers. On the other hand, he could charge more the offering of the initial system and lower the price for the future reconfigurations, if he does not want to be exposed to the uncertainty on the future. Nevertheless, based on the cost estimation provided by the focused flexibility configuration method for all the scenarios, the system suppliers can also estimate his profit level looking at the whole life cycle of the system and also comparing it to the traditional sales practice for high flexibility equipment. From the perspective of the users, the proposed configuration scheme provides him a clear idea of what the supplier will offer him, as well as the cost associated to the reconfiguration options.

If we consider the capacity guarantee business model, the system supplier is responsible to manage at own cost the production system to guarantee the customer the adequate capacity for a set of evolution paths within the contractual period. Hence, the focused flexibility configuration method provides him the most convenient solution to be installed to respect the contractual terms. However, also in this case, the effective economic terms depend on the fee for capacity use that the supplier would bid to the customer. In particular, an assessment of the contractual penalties in case the capacity is not met is not taken into consideration in the applied method. In this case, the customer will not be interested in detailed configuration issues, since the supplier is responsible for that. However, the structure of the solution can provide him significant information in order to provide enough spaces in his premises for the installation, or to check the matches for his business strategy (e.g., asking for at least a 5-axes machine, etc.).

Concluding, the presented approaches appear a very promising enabler to provide a structured set of information to support the definition of the contractual terms for the innovative business models presented. In fact, they allow to manage in a consistent way risk-sharing mechanisms in turbulent contexts. However, the application of the methodology to the industrial case showed that, at their current stage of development, they do not fully support the sustainability assessment at business model level for the following reasons.

Table 3
System configuration in the machine builder point of view.

STAGE1

Cost = € 1,850,000					
Machine tools				**LUs**	
4-axes		**5-axes**			
5		–		4	
Pallets					
A	**B**	**C**	**D**	**E**	**F**
1	5	6	–	3	1

STAGE2

Average reconfiguration cost = € 686182

Scen	**Prob**	**Reconf. cost (€)**	**Machine tools: 4-axes**	**Machine tools: 5-axes**	**Pallets: A**	**B**	**C**	**D**	**E**	**F**
S1	0.305	860,000	5	2	1	5	6	3	3	–
S2	0.076	960,000	8	–	1	5	6	3	3	–
S3	0.131	880,000	5	2	1	4	6	3	3	–
S4	0.033	1,180,000	6	2	1	5	6	3	3	–
S5	0.204	340,000	6	–	1	5	6	2	3	–
S6	0.051	640,000	7	–	1	5	6	2	3	–
S7	0.178	440,000	5	1	1	5	6	1	3	–
S8	0.022	740,000	6	1	1	5	6	1	3	–

First, the configuration approach presented takes a single optimization perspective at time, that of the customer or of the supplier, considering a single optimization function (for example, the minimization of the lifecycle costs for the customer, or the minimization of the equipment cost for the supplier).

However, to guarantee feasibility and sustainability for the innovative business models, the two points of view should be jointly addressed to find a satisfying solution for both the customer and the system supplier under a win-win logic. Hence, the proposed approaches should be extended to calculate both the customer and supplier perspectives or used iteratively to look for a win-win solution in terms of both system configuration and prices.

Second, the cost and revenue model implemented in the focused flexibility method should be enriched in order to include business model-related issues together with manufacturing-oriented aspects. As an example, the implementation of the capacity guarantee business model would require the supplier to accept significant additional logistics costs due to the need of setting-up an inventory of machines to be used for future reconfigurations, to have available a warehouse where to stock machinery dismissed from layouts and to sustain increased transportation and installation costs. Moreover he should undertake higher marketing costs for the necessity to find new contracts not to keep machine tools unused, new costs for managing the end-of-life of machinery, etc.

The cost and revenue models should also consider performance parameters other than costs, such as the advantage of establishing a more durable relationship with the customer compared to traditional business models. Finally, they should provide the capability to evaluate the impact of different hypotheses with reasonable effort (for example, the target price for equipment and future reconfigurations, the value of the ''pay per capacity'' fees, the maximum and minimum guaranteed production volumes, the associated penalties, etc.). To this aim, future research is needed to propose new integrated methods for business model design and production system configuration.

Moreover, besides business models and design methods, a cultural progress is needed to establish a deeper partnership orientation between customers and suppliers, compared to the current business relationships.

In fact, this is a necessary enabler for sharing information that customers are traditionally reluctant to provide (such as demand forecast, expected turnover, product technological trends, etc.), but that is necessary to guarantee an optimized system configuration which is profitable for both suppliers and users.

Conclusions

In this paper two promising flexibility-oriented manufacturing business models (the ''reconfiguration guarantee'' and the ''capacity guarantee'' business model) were taken into consideration, with the aim at addressing their viability. The two business models envisage a more complex way of configuring a production system during its whole life cycle. The higher complexity is mostly delegated to system suppliers, rather than to customers. Thus, the supplier provides an additional value to his customers and, consequently, also a competitive advantage to increase their market and/or to gain higher profits.

To support the increased complexity of the configuration process, the use of focused flexibility configuration methods based on stochastic programming techniques were proposed and customized. Their testing on a real industrial case demonstrated that the information content they can generate is an important support to the implementation of the innovative business models above described. In fact, they are able to optimize manufacturing flexibility and to forecast future costs and revenues taking uncertainty into account.

However, the impossibility to address also business-related variables like bid prices, penalties, contractual thresholds, etc., is an important limitation in the use of currently available stochastic configuration methods. To this aim, new integrated approaches should be developed, able to jointly consider production and business related issues at the same time.

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