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Rejuvenation of business management tools in Industry 4.0

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Abstract. The world of business economics (and management) traditionally has been viewed as relatively linear. In such context competitive dynamics depends of contingency between structural factors and contextual factors, as well as characteristics of representative company. But, context has been changed under the impact of Industry 4.0. By synthesizing the breakthroughs from cyber and physical (and/or biological) worlds, it gave rise an almost endless stream of combinatorial innovations. There are two major consequences of previous transition. First, universal connectivity as new free good enables that the world of engineering reaching the levels of complexity and dynamism typical for non-linear systems. Second, emerging amalgams of cyber and physical breakthroughs trigger in business management transformation of linear value chain into exponential value chain (or platform), actually non-linear system. Mentioned structural changes lead to convergence of the engineering and business management in conceptual terms. In this paper we explore the ways in which Industry 4.0 can offer a powerful and consistent platform for implementation of conventional business management tools. We have been inspired by two achievements. First, to map out the impact of Industry 4.0 on double paradigm change, both in macro and micro (or business) management. Second, to explore, with key details, the impact of the paradigm change in business management on effectiveness of conventional management tools. By doing this, we wish to promote the broader and systemic thinking, synthesizing micro and macro management perspectives into a single point of view that is actually based on the reversibility principle.

Keywords: Industry 4.0, paradigm change, combinatorial innovation, reversibility principle, exponential value chain, information value loop, micro management tools

1 Introduction

The Great Recession of 2008 definitely confirms that neoliberal model of growth and related economic policy platform do not lead to sustainable and inclusive growth, both toward the people (full employment and decent jobs) and the nature (environmental conservation). When a complex system like economy grows within a materially finite context and with ignorance of negative external effects and adverse implica-

tions, some deviations from expectations like financial bubbles, pollutant gases bubble, income inequality, and environmental degradation in particular, could only be explained as consequences of model's premises. The last crisis has reminded us that adherence to the current economic system represents a betrayal of future generations. No doubt, the market forces cannot stop the negative external effects and stagnation trap.

Behavior of business organizations and economy as whole should provide better balance between the society and the nature. Previous perspective has been addressed in many discussions dedicated to the new economy rules, particularly in the Stockholm Statement [2]. In contrast to the neoliberal model of growth based on market fundamentalism and the Washington Consensus [22] as related policy platform, the new consensus illuminates that the market on its own is not capable of managing serial structural transformations inspired by Industry 4.0. So, new interest around mission driven industrial policies is growing.

The impact of Industry 4.0 is ambivalent, holds both promises and perils. If not managed properly, it will exacerbate existing structural imbalances from the past, create new ones, and slowing progress towards climate crisis resolution. Business organizations and economy as a whole can no longer continue to operate under the old rules. Rewriting the rules, in fact, means a paradigm change in management. The reversibility principle (or feed-back loop) as basic principle of functioning in physical systems is foundation of double paradigm change in economics (and macro management) and business economics (and micro management).

Implementation of this principle in macro management leads to the growth model inspired by the idea of circular (regenerative or shared) economy and heterodox economic policy platform [6], both combining economic progress with environmental and social responsibility. Paradigm change in micro management triggers radical changes in business model, organizational structure, and strategy of business organizations. It enables proliferation of combinatorial innovations through economy, as a whole. The implementation of the same principle in new macro management paradigm, in fact, means broadening the existing development goals, introduction of new development initiatives focused on environmental sustainability and mission oriented industrial policies for tradable sector combined with automatic stabilizers in core economic policies (monetary, fiscal, and competition).

Search for solutions of the legacy problems is also relevant. Circular economy is alternative to linear production systems. Also "green transition" needs coordination of the visible hand of the state and invisible hand of the market. So, heterodox policy platform provides in the same time verticalization of research and development within frontier technologies development and education improvements (long life education for reskilling and upskilling workforce) through "visible hand" of the state along with horizontalization of innovative products and services through market "invisible hand".

In Industry 4.0 creation and use of actionable information giving to reversibility principle the role of a key transformation rule. Related performance improvements on a micro management level trigger the paradigm change in macro management level in the same direction. Namely, feed-back loop is another focal point which should be respected in model of growth and related economic policy platform definition.

Universal connectivity is ultimate free good in Industry 4.0. It orchestrated an almost endless stream of combinatorial innovations, by enabling a greater efficiency and superior value proposition. The explanations coming from the fact that the deeper managerial visibility of the structure of component costs combined with better insights into the client needs trigger broadening of actionable information data base and, as a consequence, adequate decisions. Above all, paradigm change rejuvenates conventional micro management tools, making their implementation more effective and efficient.

The last stance is exactly what this paper tries to promote. Our intention is to present a comprehensive picture of the ways in which the business platform as the key consequences of universal connectivity and combinatorial innovations, can offer rejuvenation of conventional micro management tools like quality control, activity-based costing, value-based management, manufacturing execution system, and enterprise resource management.

The structure of the paper follows the abovementioned. After the introduction, the second part deals with the impact of major contextual forces on paradigm change in micro management. The third and the fourth part explain the consequences of paradigm shift in micro management from two relevant angle: business model (and organization), and strategy. The fifth, and most important part, reveals rejuvenated applications of some conventional micro management tools. The last part presents some concluding remarks and thoughts.

2 Paradigm shift in business management

Paradigm change in business management is in urgent need for updating, having come under the impact of universal connectivity and combinatorial innovations.

Beside great potential of Industry 4.0, gaps around spread of noise (or misinformation), cybercrime, and problems with algorithmic biases and big data are still large. Moreover, complexity of the business ecosystem grows faster than the system itself. Figure 1 indicates that the possible interconnections (or flows) in business ecosystem grow with the square of the number of participants (or nodes). Consequently, ability to use transaction data (find, classify, aggregate, and analyze) in order to get so-called “actionable information” grows faster than opportunity of using it for concrete decision making. Indeed, it is a significant threat not only for prosperity, but also for business continuity.

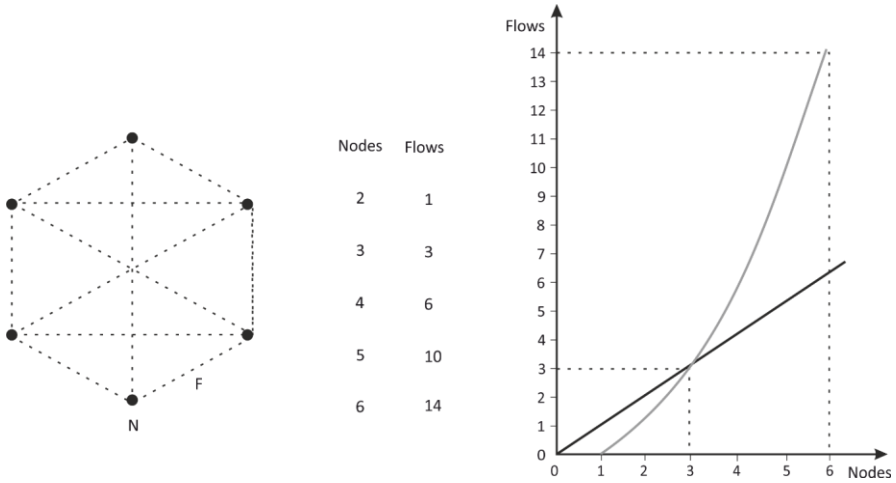
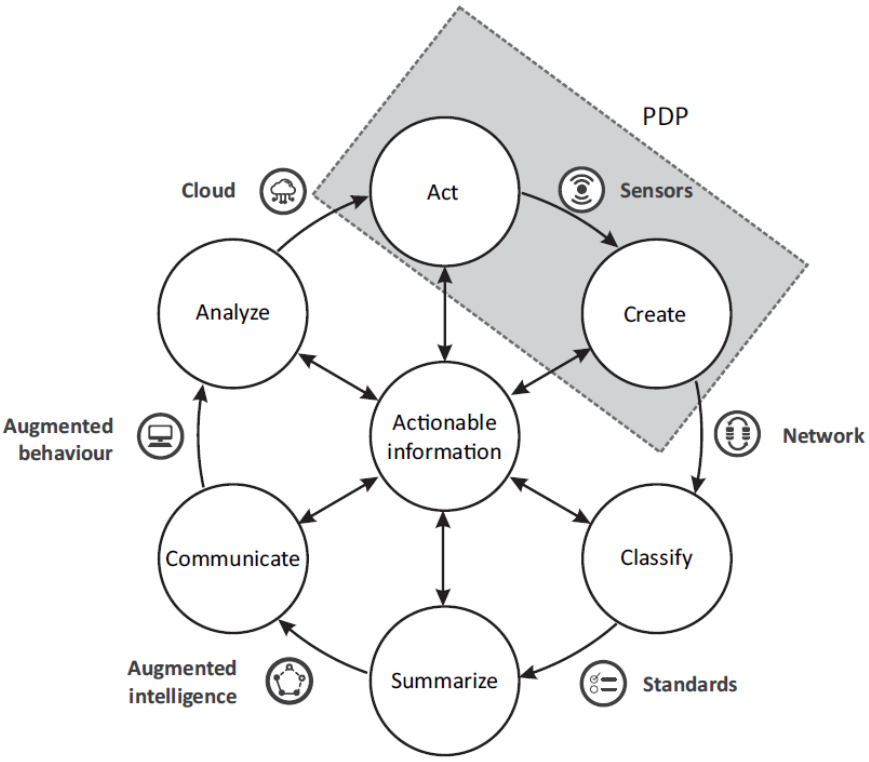


Fig 1. Relations between nodes and flows

In all sectors actionable information is prerequisite of competitive advantage. New dynamic favors the pursuit of fast growth and incentivizes business organizations to expand from value chain to value network with the aim to gain control of critical infrastructure, data flows and actionable information. In the new context reversibility principle is going to be a key rule for capitalization of actionable information.

Advanced (or additive) manufacturing, sometimes called smart automation implemented on production phase of the linear value chain is a typical example of reversibility principle. Advanced manufacturing actually is amalgam of cognitive technologies, artificial intelligence, and robotics. Cognitive technologies *via* digital tweens of the innovative product communicate with the machinery to tell it what to do on unique way.

Value creation based on information is similar process with value creation from physical value chain. "Information Value Loop" concept developed by *M. Raynor* and *M. Cotteleer* [18] is the framework that allows a multiple feed-back loops of information or flow of transaction data from physical to digital and back to physical content. It is the nexus of activities and related data that are successively created, classified, summarized, analyzed, and communicated in order to be transformed in actionable information (see Figure 2).



Source: Modification based on [18, p. 55]

Fig 2. The Information Value Loop.

Each loop consists of three activities: creation of digital record (transaction data) related to the physical activity, real time exchange of transaction relevant data between data bases with the aim of creating actionable information, and implementation of some algorithms to translate actionable information in concrete business actions (or transformation of digital context into physical context). Consequently, the concept incorporates physical-to-digital-to-physical loop (or PDP loop).

Previous example explains how reversibility principle implemented in value chain by enabling creation of the feed-back loop from physical back to digital, from digital back to physical, and from digital back to physical content. Each stage of the loop is supported by specific technologies, virtual and/or physical. For example, an activity, monitored by sensor technology, creates some transaction data. Analysis of transaction data meant to explain all kinds of analytical support of data analytics to operations stage of the value chain. Artificial intelligence helps to complete the loop. It

enables the automated and autonomous action of machinery to be implemented through actionable information.

3 Business model (and organizational structure) change

Domination of standardized technologies and/or products is one of the key characteristics of the previous stage of economic development. The related business model has been developed, more or less, as a reaction to a predictable demand pattern. Conventional business economics set of rules is based on behavior of representative company. Under such proposition, a business organization was structured for efficiency/effectiveness. This orientation leads to division of labor and functional hierarchy. Unfortunately, functional silos restrict collaboration, limit knowledge sharing, as well as identification and annulation of a competence gap. They continuously decreasing ability to react adequately to frequent, interrelated, and radical changes.

Reactive business model and functional hierarchy does not work when symbiosis of different technologies is the main rule of competitive dynamics. Being in the intersection between physical and virtual world, modern business organization has started to make digital transformation, in terms of virtualization and sharing. The combinatorial innovation as a hallmark of Industry 4.0 goes hand in hand with a cognitive diversity. Empowered network of teams is infrastructure for this symbiosis. Namely, new organization provides a network of teams. Teams must be formed and disbanded rapidly and with minimal transaction costs.

Rapid advances in connectivity and industrial internet of things (IIoT) are becoming critical for new business model. In mapping the future beyond the digital frontier, we see that singular technologies are ingredients in combinatorial innovations as well as a recipe for transformation. In the near future, the ways people interact with technology should be replaced with synchronous intelligent interfaces.

Industry 4.0 offers ongoing competitors huge and vigorous opportunities for differentiation based on advanced manufacturing and deeper client insights along with cost-cutting based on real time costing methodologies. Combinatorial innovations also create new competitors threatening incumbents, reshaping conventional value chains and industries, as well as promoting new business models with transformation power for the economy and the society, as a whole. According to *Ch. Christensen* [4], combinatorial innovations are mainly disruptive.

After digital (and organizational) transformation, there are so many possible choices for a player of the competitive game regarding suppliers, buyers, technology vendors, communication protocol providers, and system integrators [3]. To bring together different resources and technologies and make them usable in an optimal way, business organizations need facilitators or some form of platform.

A platform is a physical and virtual space enabling participants to realize their intentions. Actually, platform is a business model (or ecosystem) of business organizations in which multiple players are connected and attracted (see Figure 3). Important functionality of the platform is pricing. Namely, platform is a two-sided market space, in which one party affects the volume of transactions while balancing the price level paid by the other parties.

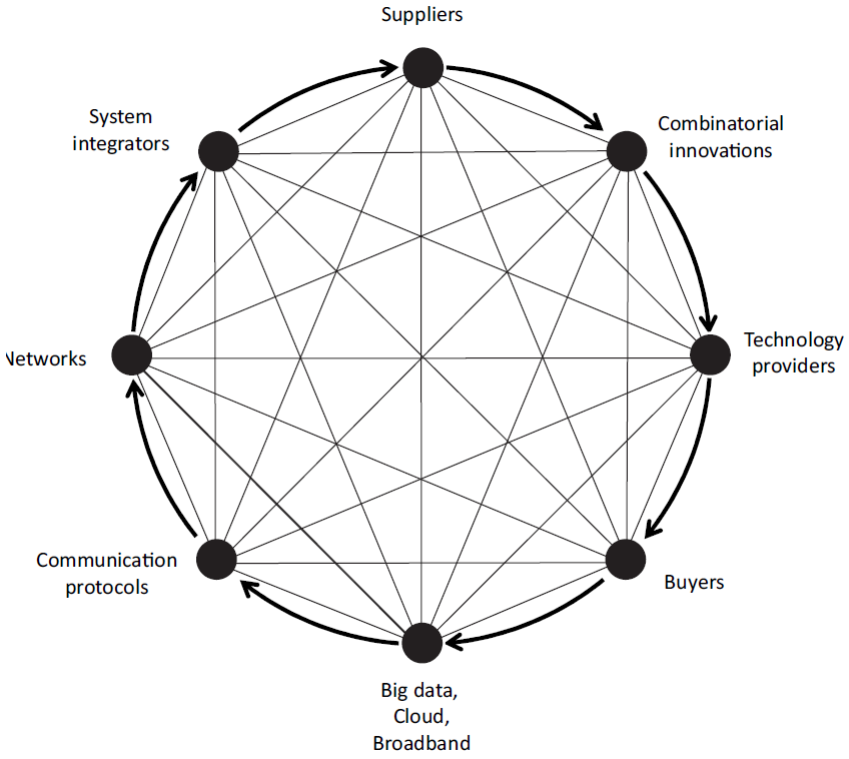


Fig 3. Platform as a business model

Platform connects different technologies in a combinatorial way. Technologies, from sensors and communication protocols, to networks technologies like 5G, data analytics (big data, cloud computing, broad band, etc.), and cognitive tools and, their integration within IIoT, artificial intelligence, virtual reality, etc., are key enablers of growth. Members of the emerging ecosystem then use row technologies to create tailor-made solutions with the aim to reach the user's demand simultaneously with cost reduction. Technology suppliers provide alternative pathways by offering a pos-

sibility for different users to find relevant content, services, and solutions within a platform.

Indeed, the platform provides trial-and-error mechanism for new combinatorial innovations. Companies frequently use prototyping to learn about the potentials of some combinatorial innovation before performing a large scale production. Thinking about big ideas and starting with small implementation is compatible with fast scaling. Along diversification effect, economy of scale effect is also possible, even for niche player, based on the agglomeration effect on global market.

In the face of identified opportunities generated by the platform, many companies are diving precipitately into digital transformation. To escape obstacles on this journey, related tools remain valuable guide.

4 Broadening the strategy scope

Conventional business economics proposes that the perfect market structure leads to optimal resource allocation. In such case, beating rivals is the purpose of strategy. Competitors which calculate higher profit margin on total cost and marginal costs are ready to decrease the margin keeping in mind that any competitor entering the industry will contribute in aggregate supply only if its price covers total costs per unit, at least. Fundamental defect of such line of reasoning is that such market structure is more or less static, as well as the positioning based on pricing strategy.

Static industry structure and static positioning are irrelevant when continuous stream of combinatorial innovations influences dynamic competition, by making new entry, substitution effect and, even more, disruption of incumbents. When "disrupt or be disrupted" is the name of the competitive game, without adequate strategy the threat of being left behind the technological frontiers increases dramatically.

In *M. Porter's* strategy formulation framework, [14] and [15], the key to success in the competitive game lies not in a low price with the aim of taking away the market share from the main competitor, or eventually from the whole market ("winner-takes-all"), but in ability to create a unique and value-based competitive advantage. When competition is based on actionable information, a better analogy for industry dynamics might be the win-win instead of the zero-sum-game.

The level of complexity, rapidity of change, uncertainty, mutual interactions, and the level of ambiguity that strategists need to deal with in modern business ecosystem are going up. Indeed, the deep understanding of major forces of change helps to amplify their transformative power beyond *M. Porter's* framework promoting cost-cutting, differentiation, and focusing as generic strategy options.

The paradigm shift in micro management means that the focus of strategy covers not only cost reduction, but also, and predominantly, the value creation. Namely, cost-cutting and differentiation are not mutually exclusive alternatives. Robotics, smart

automation, and cognitive technologies can lead simultaneously to cost reduction that is much more significant than the historical standards, while still allowing much higher consumer satisfaction.

Interaction between the borderless environments (both internal and external) with the fast development of frontier technologies causes transformation from linear to exponential value chain. Respect toward mentioned requirements needs broadening of the strategy scope. In *M. Porter's* terminology the value chain is perceived to be linear. Connectivity makes the linear value chain augmented by transforming it into exponential, dynamic value chain with circular feedback loops of resources, money, and information.

In the new setting the collaboration dominates over competition. Collaboration enables platform participants to optimize their global footprint, by building strategic alliances across the platform. We live in the era when the technology change is facilitating the formation of strategic alliances and partnership with external parties which can deliver different material components and intangibles in the value chain of single participant. In the new context, the linear value chain of one industrial organization needs to be understood as a part of the exponential value chain or network of independent value chains of suppliers, customers, competitors, innovative start-ups, online sellers, off-line sellers, and other stakeholders (regulators, platform providers, cloud providers, big data providers, etc.). Figure 4 provides a schematic view of the exponential value chain.

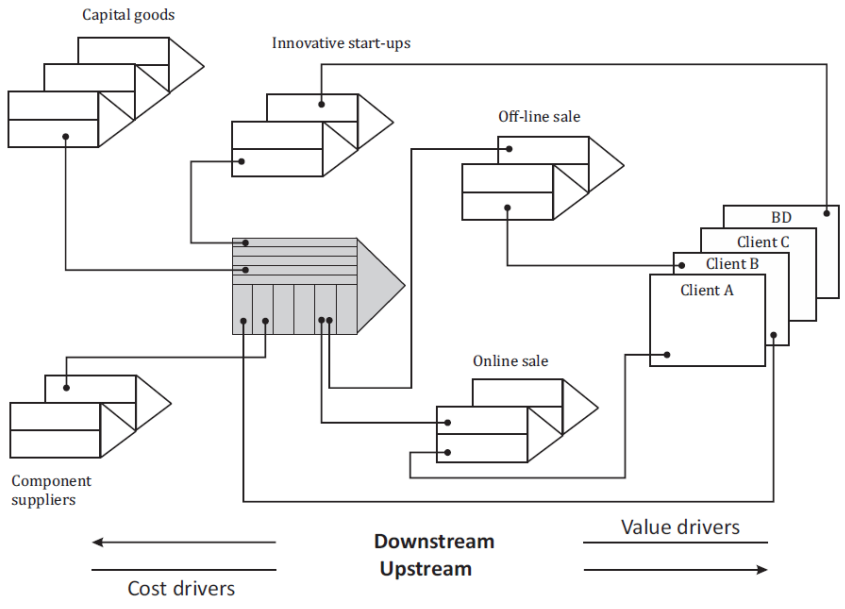


Fig 4. Exponential value chain

The exponential value chain is the weapon to trounce rivals based on strategy, particularly keeping in mind that in an environment with endless combinatorial innovations multiple winners can thrive and coexist.

5 Deconstructing rejuvenation of micro management tools

Changes in the focus and the scope of strategy already discussed triggered rejuvenation of some tools and their alignment in strategy formulation and implementation. The following analysis exhibits certain evolutionary links between traditional framework and contemporary practice.

5.1 Quality management

The Industry 3.0 with ICT breakthroughs in the background of operations, actually, boosted the usability of the variety of quality control management techniques. Since early 1980s, inspired by “zero defect”, adoption and improvement of the quality control management techniques such as Six Sigma [13] and Total Quality Management [1] was growing.

In Industry 4.0 the new wave of ICT breakthroughs, along with combinatorial innovations from virtual and physical world, enable continuous quality control (actually “controlling”), or the shift from intermittent quality control to strategic quality controlling.

The new concept is based on a triple feedback loop (see Figure 5). Let us suppose that one of the strategic initiatives to improve market position of a company producing machinery is to increase the life span of key components of its products. First activated feedback in the process is strategic learning. This feedback contributes to the formation of the digital twin of innovative products. Artificial intelligence uses data from data analytics, based on cognitive technologies. The second feedback considers making forecasted value based on resource allocation in advanced manufacturing. The third feedback is a traditional quality control feedback. Sensor technology can create information about the rotation, vibration and temperature of machinery communicating transaction data with the central server where they can be classified, aggregated and analyzed through artificial intelligence in conjunction with standards and clients' expectations identified by cognitive technologies. In doing so, a business organization can create predictive model of failure of the key parts, taking actions on maintenance only when failure is likely. Such system of strategic quality controlling would create value in the form of extended pre-maintenance life time of the machinery and reduced maintenance costs.

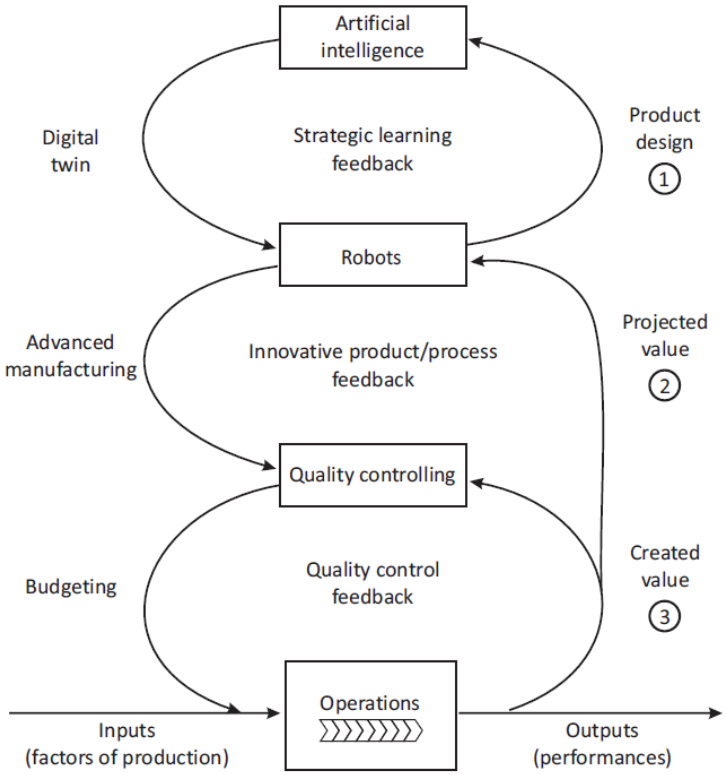


Fig 5. Strategic quality controlling

5.2 Cost management

Activity-based costing (ABC) is the tool developed in Industry 3.0 with the aim to solve deficiencies of standard costing method by covering all activities that drive costs.

The method is causing an organization to manage activities not costs, recognizing the cost as simply an outcome of undertaken activities. This method has been inspired by cost optimization through identification of specific drivers for direct costs and overhead costs (secondary and tertiary) depending on the activity from the value chain.

ABC assumes two steps. First, resource costs are tied to activities in the value chain, using various resource drivers. Second, activities are tied to cost objects (products, parts, services, etc.), using various activity drivers. Cost optimization is based on linking modules (or activity pools) by using resource and activity drivers which show the relationship between the sources of costs and destination and allocation of activity cost pool to product/services.

In Industry 4.0 we see dramatic changes in cost structure making ABC a more attractive costing method. Overhead expands significantly, particularly inspired by digital transformation, emerging as a major component cost. Also, variability of overhead is a matter of fact. Overhead variability is driven in accordance with the range and complexity of the products, customers and selling channels. When overhead dominates direct cost and variability of overheads is a matter of fact, ABC is more relevant costing method than direct costing.

Initially, the concept proved highly useful during the mass automated production [7] and [12]. In this way ABC led to efficiency improvement and performance measurement improvement. Also, it provides better base for optimization of the product mix [5].

Also, ICT breakthroughs offer new possibilities regarding costing methods since they allow for real time data acquisition and the shift toward real time ABC {21 and [19]. Namely, the data about resource drivers and activity drivers are collected in real time using sensor technologies (ID readers, RFID, etc.), and other virtual technological breakthroughs like IIoT, BD, cloud computing, broadband, etc. New technologies rejuvenate conventional ABC which is, in some sense, time consuming and costly, difficult to scale and related with granularity of data problem. Also, ICT breakthroughs embedded the use of real-time ABC in the wider context as a decision support system that provides a robust basis for business analytics.

5.3 Performance management

In Industry 3.0 cash flow became key metrics in performance measurement system ("cash is a fact, profit is an illusion"). Related performance management system is based on the creation of the value through identification, measurement, and the use of broader base of value drivers as factors increasing cash inflows and cost drivers as a factors influencing cash outflow increase. There are various techniques evolving from *A. Marshal's* concept of economic profit to economic value added [16], [17]. Balanced Scorecard (BSC) developed by *R. Kaplan* and *D. Norton* [9] as a truly holistic tool actually integrating leading indicators (or cash flow based) and lagging (or profit based) indicators of the company success.

Mentioned tools provide ground breaking advance in assuming more strategic approach to performance measurement system [8]. The overall comprehensive platform integrating a number of interrelated techniques aimed at maximization of the client/customer' life time value with shareholders' value is known as Value Based Management or VBM [23].

5.4 Strategic management

In the Industry 3.0 Enterprise Resource Planning (ERP) performs as the backbone of decision support system. Unfortunately, ERP is capable of supplying strategists predominantly with cost data. However, this is one way of supplying the actionable information, integrating the data about standardized costs. Also, traditional ERP system

provides the information on a aggregate level, while real time records about working hours, utilization of machines, material loss, and the like can hardly be provided.

Manufacturing Execution System (MES) is a hallmark of operations management. MES will make an optimal production plan by considering how to arrange the advanced manufacturing in accordance with formulated strategy [10]. In the operations stage of the value chain, all resources are tracked and their real time status data is displayed in the MES. Namely, the production line can be broken down into individual machines to collect the data (quantity of raw material, machine time, manpower time, etc.). Also, the collection of the quality control data can be used to achieve quality management.

We are living in a time when innovative products and processes fundamentally determine the strategic vision. An innovative production strategy is a way to reach strategic objectives based on frontier technologies, enabling the implementation at various points of the value chain, particularly in front stages (design, construction and digital twin) and operations. Figure 6 represents a simple abstraction of two building blocks of the strategic management process including micro management tools like ABC, BSC, VBM, and ERP as hallmarks. The flow diagram is used to simplify complex relations, decision-making points, and feedback loops that lie in the background.

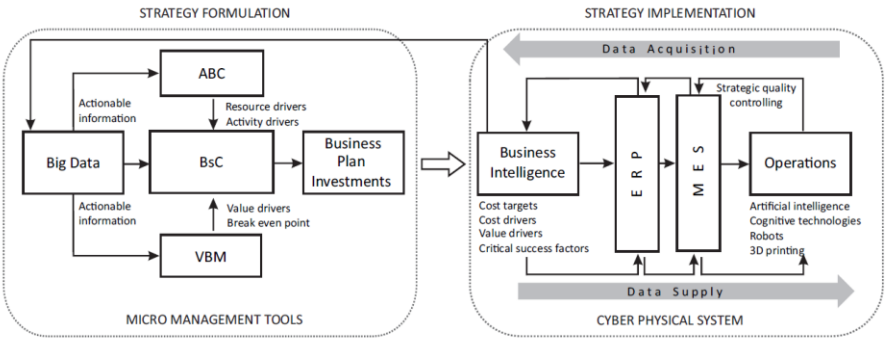


Fig 6. Business management tools: integrated view

Executing strategy is about organization focused on strategy. In fact, it is about managing performance toward predetermined direction. Big Data combined with Business Intelligence is going to be the core of emerging real time ABC, BSC and VBM based on them. Precisely, real time ABC provides actionable information about resource drivers and activity drivers and VBM provides break-even and value drivers, all playing the role of inputs for strategy formulation based on BSC.

VBM is also a complementary method with strategic management based on BSC. More precisely, VBM aligns management processes of the quality control and strategic management with the value creation [24]. VBM plays across several areas like

formulation and implementation of the strategy with the highest potential for the long-term value creation, identification of the key performance indicators and their correlations with value drivers on a company, business unit, product, brand, or customer level.

The very essence of the operational part of the VBM is the identification of the specific performance variables or "value drivers" that lead to value creation given the business strategy. Industry 4.0 impacts the value drivers in two ways. First, in the digital environment there are new value drivers, such as strategic quality controlling (or digital quality management) in the quality control area, real time supply chain optimization in the inventory management area, human-robot collaboration and digital performance management in the operations area, etc. On the other hand, improved MES allows real time data acquisition about value drivers. This way the information about the value drivers plays the role of the lead performance indicator.

Big data, cloud computing technologies, and broadband technologies can be used for real time decision making. Namely, after real time data acquisition, a machine-to-machine data feedback allows for the advanced manufacturing. The entire cyber-physical system is used to integrate the data to automatically manage and control production processes in real time, as well as to measure the operating performance [20]. As a result, decisions about innovative products, optimal product mix, equipment layout, and production protocols can be made to achieve the defined value proposition.

Thanks to the ERP-MES link, operations management database turns transaction data into actionable information. During the strategy implementation, all resources used are tracked with real time ABC.

These days, ERP is only one way of supplying standard costing. The strategy formulation is derived from the immense quantity and quality of information used for identification of the demand level, resource drivers, activity drivers, and value drivers. When translating strategy defined in BSC format into a business plan and investment projects, the cost drivers, the cost targets and the value drivers simultaneously play the role of the critical success factors, operating goals and the performance measures. Before the operations take place, MES database integrates the information about unit quantities for material, labor, and overhead, and the value drivers turn them into actionable information (production process mapping) thanks to the ERP-MES link [10]. Namely, in advanced manufacturing environment, VBM, BSC and ABC are embedded in ERP system and, then connected to MES.

6 Conclusion

In Industry 4.0 business management and engineering are viewed as non-linear systems. In both cases reversibility principal is going to be a silver lining of systems

being managed. Considering previous, in this paper we briefly present a snapshots of recommendations based on views of economists supporting circular economy new deal and heterodox economic policy platform.

Summarizing the emerging contours on new paradigm in business economics (and management) we see that business organization of the future should be concentrated not only on further cost reduction, but first and foremost, on combinatorial innovation and value creation, not violating circular economy proposals. Harmonizing contradictory requirements of different stakeholders with the sustainable and inclusive vision of future development, the company of the future is going to be the "symphonic company" with new way of competing and the new space of positioning.

The symphonic company will change the strategy focus and broaden the strategy scope. Key consequences of these changes are combinatorial innovations as proposition of competitive dynamics and exponential value chain (or platform) as space or infrastructure. Both changes influence rejuvenation of some conventional business management tools and their improvement with new functionalities. Tools like strategic quality controlling, real time ABC, advanced BSC, VBM, and new releases of MES/ERP are in focus. Along with IIoT, BD, cloud computing, broadband, 5G network, and other components of the digital infrastructure, these tools define the new way how data are being acquired on a real time basis and transformed into actionable information through the Information Value Loop to create values which are environmentally not damaging. Before the operations take place,

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