Industry 4.0 and Smart Manufacturing: Data Challenges and New Innovative Contracts for Program Management[1, 2]

Sonia Bouden

ABSTRACT

Industry 4.0 is considered a groundbreaking and strategic step in manufacturing and heralds a new age of connected machines. Through smart manufacturing, industrials can achieve higher productivity and performance, drive down costs and time, and improve the productivity in projects, by marrying the physical and digital systems.

However, when smart machines are involved, connectivity between devices and exchange of data can be problematic in Project, Program and Portfolio Management. It can bring with it, security and confidentiality issues and data dissemination risks. The owner of the company and the suppliers strive to forge new revenue streams and race to get the most benefit out of the new technologies, so the competition is greater and the challenge to secure data becomes all the more crucial.

The focus will of this paper is to develop a full contractual approach to help industries investigate the best options when contracting and implementing new machinery.

Using the non-Compensatory model technique, the additive weights technique, and by conducting a Pareto analysis, we chose the best alternatives for companies and suppliers to define a well-structured contract, by focusing on the impact that these criteria can have on the projects.

Keywords: Smart Manufacturing, Smart Machine, Confidentiality, Intellectual Property, New contracting approach

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INTRODUCTION

The world is facing new challenges related to economic, social, environmental and sustainable manufacturing systems. Many businesses are embracing the need to adopt smart manufacturing and move towards industry 4.0 and process automation with highly sophisticated technologies, in order to decrease their costs, shorten the manufacturing time and improve their productivity and performance in their projects. This brings to mind that adopting smart machines cannot be considered as a simple, unique project. Smart Manufacturing has a significant impact on how a factory organizes itself and the absence of digital and data trust makes the project portfolio quite complex. In this context, it can be interesting to link with the definitions of the Guild of Project Controls Compendium. We can consider the following examples:

		Guild of Project Controls Compendium and Reference[3]	Smart Manufacturing and Industry 4.0[4]
Project		"A project is either an investment or cost center (cash out) from which we expect a return on that investment (RoI) or on asset (RoA), through increased revenues, reduced costs, or increasing intangible value through corporate social responsibility projects."	Implementing new machinery is a big investment for the company at the beginning, so "most companies believe they will see a return on investment within two years or less, a third of companies expect a longer timescale of three to five years, and only few think that it will take any longer than five years for Industry 4.0 investments to pay for themselves."
Program	Strategic Program	"A Strategic Program delivers assets and benefits that attain directly the sponsoring organization's future state and influence the decision-making process."	Industry 4.0 has such a big impact considering that smart machines enable "shorter operational lead times, 2,9% of increase in annual revenues, 3,6% drop of costs, higher asset utilization" and maximum product quality. This represents "US$421 bn in cost reductions and US$493 bn in increased annual revenues p.a. for the next five years."

[3] GUILD OF PROJECT CONTROLS COMPENDIUM and REFERENCE (CaR) | Project Controls - planning, scheduling, cost management and forensic analysis (Planning Planet). (n.d.). Retrieved from http://www.planningplanet.com/guild/gpccar/introduction-to-managing-project-controls
[4] (n.d.). Retrieved from https://www.pwc.com/id/en/CIPS/assets/industry-4.0-building-your-digital-enterprise.pdf

	Operational Program	"Deliver assets (benefits) that reduce the critical impact to the owner's day to day operations."	The systems used in industry 4.0 deliver data collected via sensors, data collected internally and externally (from suppliers, customers, stakeholders, and partners). Data allows to carry out preventive maintenance.
	Multi-Project Program	"Create synergies in projects, which are sharing resources, common clients, or similar technology."	Since machines communicate and exchange data (the technology), there is a new way of working together (cooperation) between the devices, and a synergy (consensus) between suppliers and owners, whose primary interest is improving the technology (algorithms and data), resources (machines), assets and performance (quality and productivity).
	Mega-Project	"A larger project than the sponsoring organization's typical projects that deliver a specific asset."	Basically, the owner and suppliers are looking forward to improving the 'product throughput time' (the asset is planning and enhancing asset uptime and schedules), predicting in advance a maintenance, before the machine breaks down (the assets are algorithms and data analysis), in order to boost the quality of the final products.
Portfolio	Portfolio of Projects	"It is an investment in a "mix" of projects," from which we try to generate the best outcomes, that is to say, "minimizing risks and maximizing returns."	Industrial companies implementing smart manufacturing systems would use data analytics (to help them have a better knowledge of the customer), and also sensors, connected systems (to drive the decision-making process

	Portfolio of Assets	"Owner or Contractor has a portfolio of assets that means a set of resources, which are dedicated to the projects, with the aim to generate those resources into the most desirable return."	successfully). This way, they can save costs and make margins.
Assets	Information	"A tangible or intangible, benefits."	Generally, the major Project Controls criteria for the manufacturing industry are cost, quality, productivity, planning, risk and performance and with the development of connectivity, we can have a better insight and control of the measurements. "Data fuels Industry 4.0".
	Human		Companies tend to hire cross-functional expert teams (having a culture of digital technologies), able to experiment, innovate, and focus more on the strategy than the tedious operational tasks that can be delegated to the machines. This way, they can add real value to the company.
	Physical		Industry 4.0 uses connected systems, cloud technologies, 3D printing, greater automation, augmented reality, intelligent algorithms and IoT.
	Financial		There is a high investment in machinery required first, but even a greater budget for the change management, implying implementing the systems but also the culture of new technologies inside the company.

	Intangible	"Assets that don't have a physical presence, including sharing tacit knowledge, application, processes and relationships" [5]	"Licenses and patents" are not so secured, since the machines are communicating with each other. For the owner, it is even more dangerous, since the suppliers have access to the "customer lists" and processes.

Table 1- Digitalization as a Project Portfolio[6]

But how do the results and data, obtained from these assets, influence strategic decisions and the future state in the specific context of industry 4.0? We are now talking about smart connected machines that are communicating with each other, learning from previous experience, but also from human behaviours. These machines can replace operators and liberate staff from tedious and repetitive tasks. These technologies are evolving so fast, that they don't even require anymore that much supervision or maintenance, as before, during the production process. The control process would be done automatically, and the controlling machine can give its feedback to the production machine for adjustment, correction or any sort of change on the production process, to better fit the standards and to the quality restrictions. Smart Manufacturing and industry 4.0 seek to respond to more complex and sophisticated process optimization problems through the IoT and communication between machines. McKinsey predicted in 2013 that "Machine-to-machine communication would know 300% of growth over the five next years"[7] and in fact, the "annual investment in Europe of the German industry 4.0's market in innovative systems of production, is close to € 91 billion which would represent 1,350bn € by 2030."[8]

"Any organization or Contractor has a **portfolio of Assets** available to dedicate to Portfolios of potential projects, with the objective being to generate the most favourable return on those assets."[9]

Therefore, this amount of data becomes a critical output to the Asset, Program or Portfolio Management and decision making.

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[5] 9 Examples of Intangible Assets. (n.d.). Retrieved from https://simplicable.com/new/intangible-asset-examples
[6] By Author
[7] Disruptive technologies: Advances that will transform life, business, and the global economy (n.d.). Retrieved from https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/McKinsey%20Digital/Our%20Insights/Disruptive%20technologies/MGI_Disruptive_technologies_Executive_summary_May2013.ashx
[8] Disruptive technologies: Advances that will transform life, business, and the global economy (n.d.). Retrieved from https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/McKinsey%20Digital/Our%20Insights/Disruptive%20technologies/MGI_Disruptive_technologies_Executive_summary_May2013.ashx
[9] GUILD OF PROJECT CONTROLS COMPENDIUM and REFERENCE (CaR) | Project Controls - planning, scheduling, cost management and forensic analysis (Planning Planet). (n.d.). Retrieved from http://www.planningplanet.com/guild/gpccar/introduction-to-managing-project-controls

Given the current pace of automation in industry, there might be a worrying face in this increase of data exchange and network between the machines. Consider a company "C", producing products in its factory as designed in the model below. All of the processes until now have been made internally and kept secret, as it is its business expertise. It has always had a clear, well-defined contract with all of its subcontractors, stipulating the confidentiality clauses for its internal products manufacturing processes, and protecting as well, their intellectual property, when designing for the company "C", the needed machines.

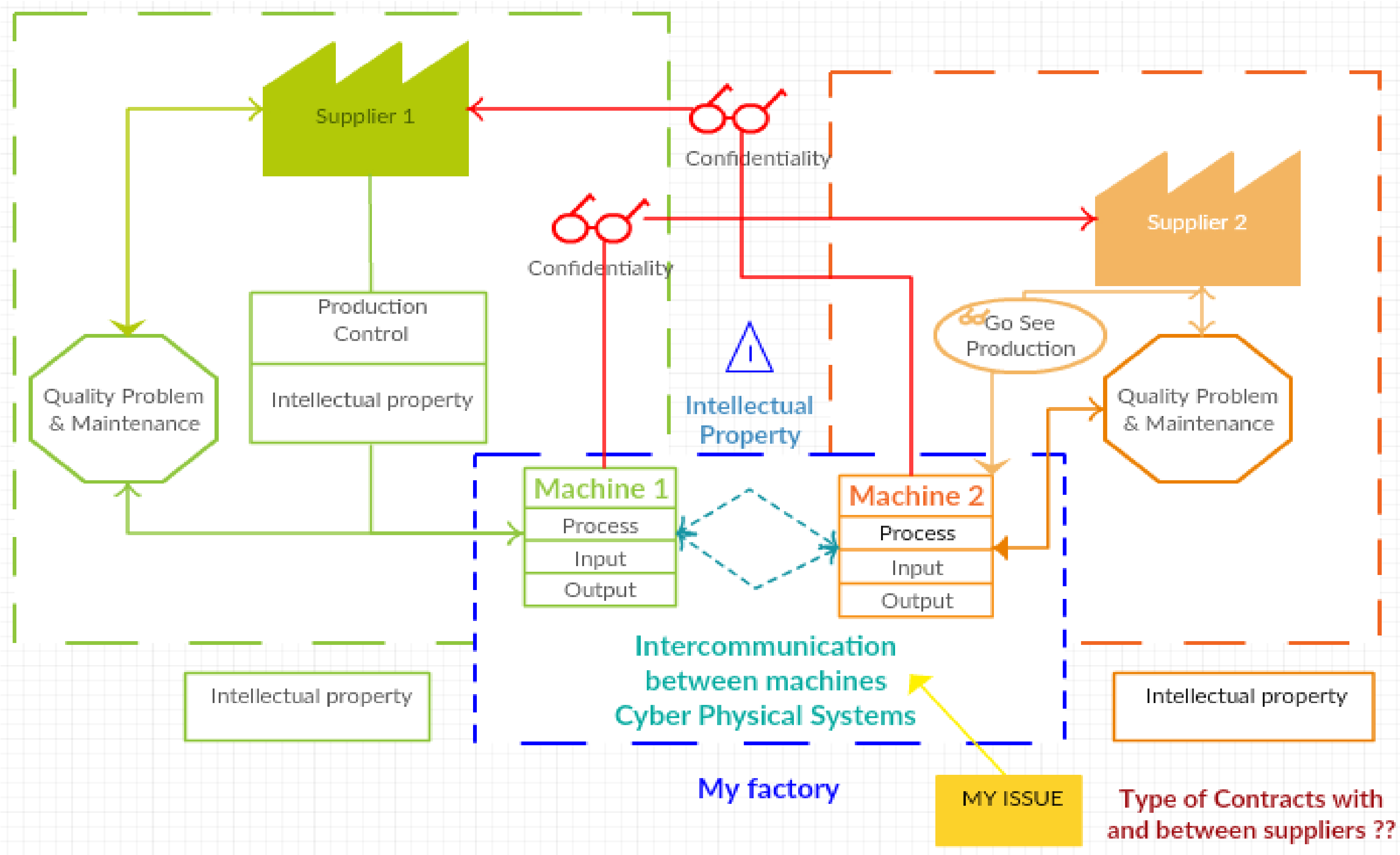

Figure 1- Process Flow Chart[10]

Thanks to Industry 4.0, the machine suppliers have even improved their services, since they can now collect data, predict machine breakdowns and prevent them. Maintenance can be done remotely as soon as they detect potential failures.

So far so good, you might say. This predictive maintenance enhances "C" company's productivity and mitigates the risk of stopping one of its processes - but then comes the poison arrow.

[10] By Author

The first issue is that the machine supplier has access to "C" company's internal information process, such as the cycle time of each one of the processes: the idle time due to setups, the work in process turnover, the manufacturing cycle time and also the performance schedule timing, until obtaining the finished products. This amounts to say that, the machine supplier, who continuously wants to improve the performance of its machine, now knows really well, the "homemade recipe" of "C" company's products and each one of the processes made by the connected machine for each product manufactured in the factory.

Then comes the second issue. We are working in a specific context, where machines are interconnected, that they communicate with each other, and exchange information about production processes. And let's imagine that the company deals with different machines' suppliers. The production line follows a push approach and the machines are in line. So, the first machine sends a signal when finishing the first process to the second machine, which waits for the data received to initiate the next process. Those two machines interact and exchange data about the time and work in progress. Hence, this raises two other major problems. The first supplier with whom I signed a confidentiality contract to keep secret the process of the machine designed, has now access to additional information about other operations not mentioned in the contract, via the other machines connected to his machine.

Second, not only does he know about the processes in the factory but also about the work measurement overall equipment efficiency and the actual processing time of each equipment, belonging to other competitors. Yet, these two machine designers who are my suppliers, have never signed any intellectual property contract with each other.

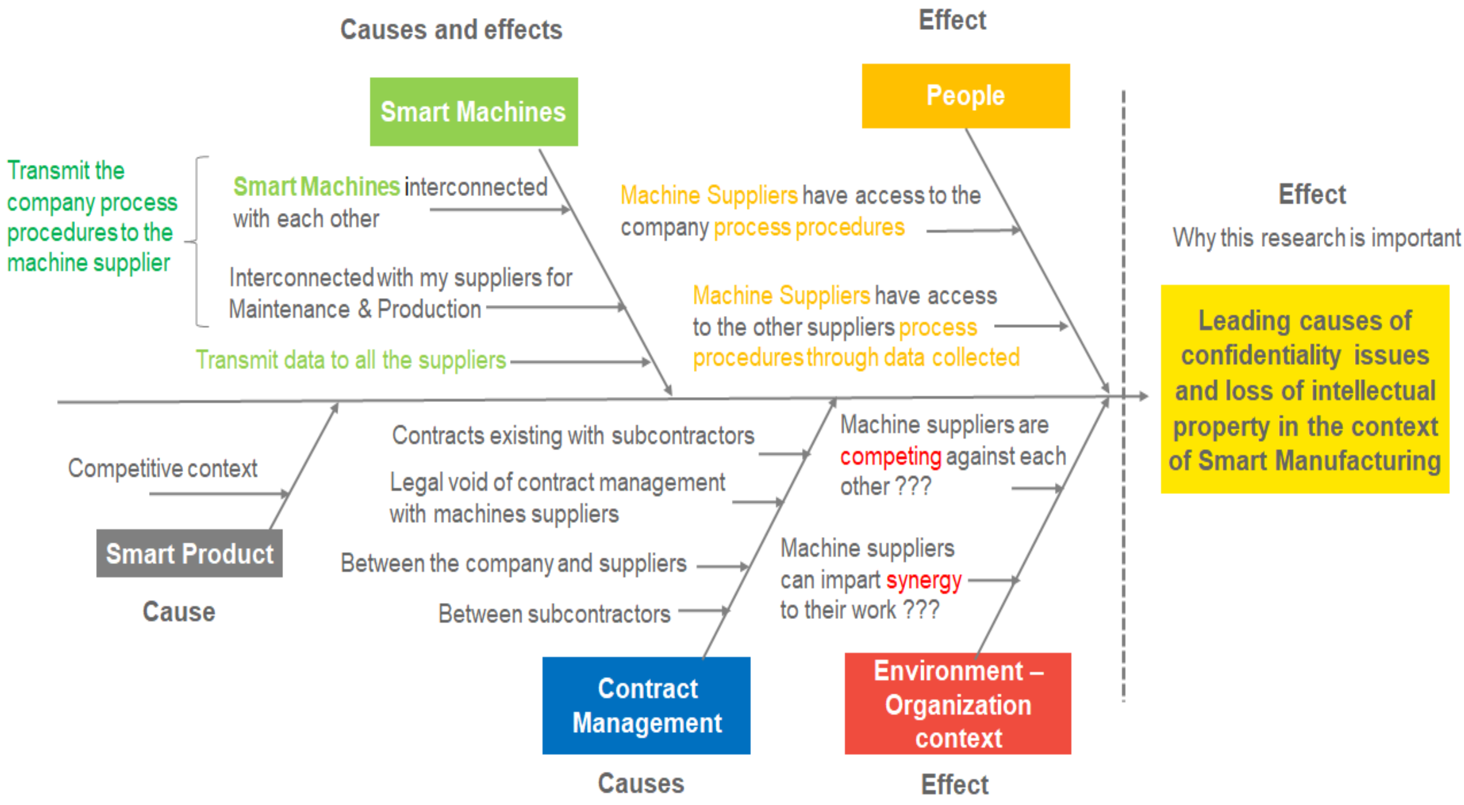

Figure 2- Cause and Effect Diagram[11]

These quite sophisticated machines indeed allow less human effort, better productivity, reduce costs, time and defects. However, there is an emergence of **new contract issues** and challenges, which are essential to consider, because they will influence how organizations manage this new context and will undoubtedly cause profound changes in the industry, due to the human-machine and machine-machine interactions.

In such an innovative environment and with all these smart networks, which contractual approaches should we use with customers, suppliers, and subcontractors and how can we manage the interoperability and integration of the cyber-physical systems?

METHODOLOGY

The purpose of this paper is to present a precise method of Project and Program Management when defining a **contractual approach** between an owner and suppliers in the context of smart manufacturing and industry 4.0.

[11] By Author

Indeed, the contractual approach between the company and the machines manufacturers has such a decisive prior strategic role and critical impact on the success or failure of the project, program, or Portfolio.

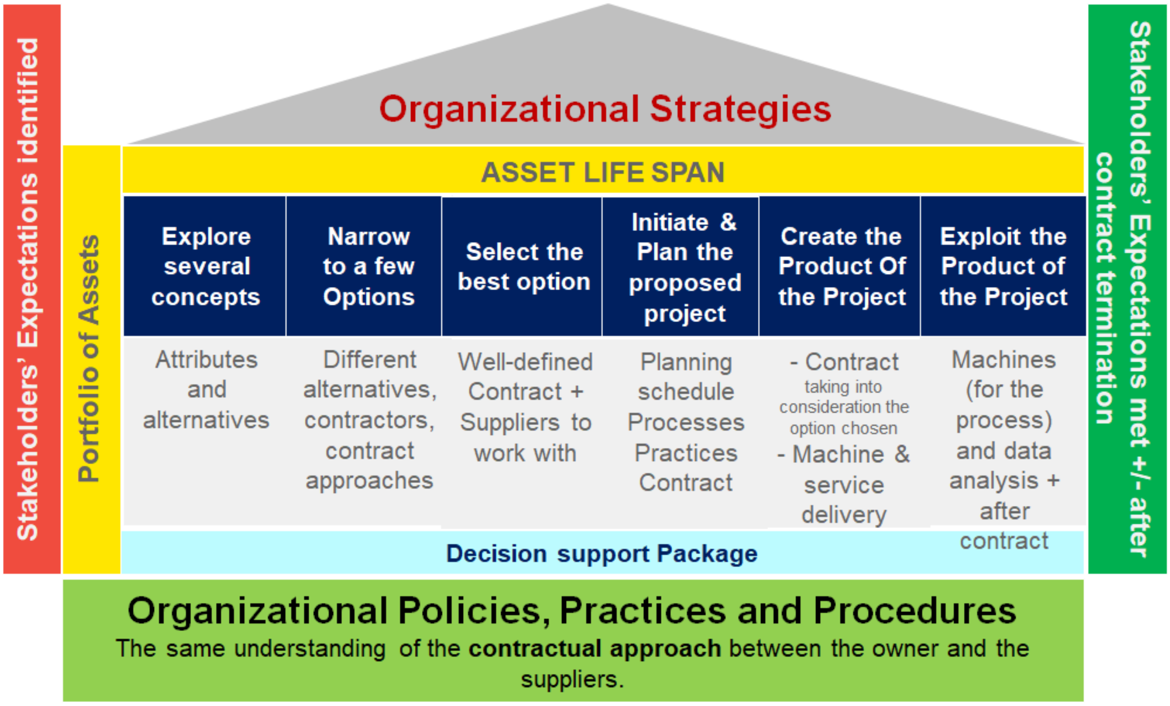

Figure 3- Process groupings and important phases of the Asset Life Span[12]

The above-graphic illustrates how important the timing and planning management, choice of stakeholders, and defining a well-structured contract, important to the portfolio **Asset lifespan** and practice of **project controls**, so before starting the program of integrating new machines, the prime concern of the owner, is to define these phases and to question if the type of contract and approach he wants to have with their suppliers should be defined first, or if they should choose their suppliers first and then negotiate the contract approach.

Contract management and schedule and process management do begin before the project begins. Given the strong interests of the owner and suppliers, it becomes hard to manage the portfolio as a whole.

If a technical solution or a cutting-edge product (**the project**) is obtained thanks to the exchange of information between smart machines or collaboration of many stakeholders (part of a **portfolio**), the result for the owner and machine designers, will be, a growing race seeking more and more data and tapping the full potential of it, which may lead in many cases to conflicts between them.

[12] By Author: GUILD OF PROJECT CONTROLS COMPENDIUM and REFERENCE (CaR) | Project Controls - planning, scheduling, cost management and forensic analysis (Planning Planet). (n.d.). Retrieved from http://www.planningplanet.com/guild/gpccar/introduction-to-managing-project-controls

For that reason, contract management is at the very core of Project Management. "**Contract types** are based on scope definition and define the degree that risk is shared between an owner and contractor, while **Project Delivery methods** are management strategies which owners can choose when deciding who and how they want the project managed."[13]

In our model, we can draw a comparison with the contracts where **owners and contractors** (machines suppliers) **share the same risks** (confidentiality, intellectual property, access and exchange of data, intercommunication, termination of the contract, conflict resolution, etc...)

Undeniably, when integrating new machinery in a factory, the contract is the solution to all the risks encounters. Contract Management and defining the structure (steps) and strategy of implementation, the requirements of changing procedures, and governance are all inherent in the critical success factors of a project evolving towards smart manufacturing.

What are the most critical decisions that have to appear in the contract and that we need to make during the earliest phases of the project that will entail the planning and the whole Project and Program Management?

Step 1: Problem recognition, definition, and evaluation

The new issues for projects and programs when introducing new machinery in a 4.0 factory are:

- Define a stringent contract between an owner and suppliers to manage the project, portfolio or program
- Choose the right contractual approach and manage the schedule and planning of the processes accordingly.

Step 2: Identification of the Feasible Alternative Solutions and attributes to measure, assess and evaluate each alternative

We will assume that all the characteristics are equally important and will use the non-compensatory model technique with multi-attribute[14] decision model based on Dominance of the alternative that better satisfies these attributes.

Alternative 1[15]**:** There are clear contracts between all the suppliers and the company (supplier-supplier and company-suppliers) concerning the confidentiality clauses and intellectual property, but there is no consensus between the suppliers. Each time a new supplier is involved, the new party agrees on predefined existent contract clauses. Still, there would always be a fear of intellectual property and confidential information loss after the contract is terminated. So well

[13] GUILD OF PROJECT CONTROLS COMPENDIUM and REFERENCE (CaR) | Project Controls - planning, scheduling, cost management and forensic analysis (Planning Planet). (n.d.). Retrieved from http://www.planningplanet.com/guild/gpccar/managing-contracts-select-project-delivery-method-contract-type
[14] 10.3.3.7 Multi-Attribute Decision Making. GUILD OF PROJECT CONTROLS COMPENDIUM and REFERENCE (CaR) | Project Controls - planning, scheduling, cost management and forensic analysis (Planning Planet). (n.d.). Retrieved from http://www.planningplanet.com/guild/gpccar/managing-change-the-owners-perspectiv
[15] Muti-Sourcing : a new way of contracting Thomson Reuters Practical Law Retrieved from https://uk.practicallaw.thomsonreuters.com/1-545-5075?transitionType=Default&contextData=(sc.Default)&firstPage=true&comp=pluk&bhcp=1#co_anchor_a202224
Some advantages and disadvantages of multi-sourcing compared to prime contracting

leveraged the confidentiality clauses are, there would still be a competition between the suppliers, which creates a need always to propose higher added value machines.

Alternative 2[16]**:** Every supplier gets information concerning the processes in the factory and information about machines without any contract or agreement between them. Suppliers cannot rest on their laurels and are always eager to make the best of this stiff competition.

Alternative 3[17]**:** All the suppliers agree to create a coalition or a consortium, (which quells the fear of information loss) and offer one unique service to their customer. The owner (company "C") chooses one group of suppliers, which are already working together in a regular basis (this can happen only if the process is a common one; if it is a matter of an original process, then such solution is not easy to find on the market).

Selection criteria

To rank the three alternatives and to accept the best one, we chose the following attributes:

I. **Security of transmission and access requirements**[18]**:** The contract clause specifies which stakeholders have access to the data. Either the information is encrypted and only the authorized persons and systems have a key that enables them to read and use the information, (always with a risk that the system gets hacked and the data is disclosed) or there is no legal vacuum, and in that case, if the stakeholders have omitted to protect their data, too bad, others would take benefits of it, thanks to their machines interconnected and would probably sell this information or use it to identify better techniques for their own machines.

II. **Opportunity of cooperation between suppliers to provide a higher quality of services and products**[19]**:** Different suppliers can pool up to come up with one unique pack of services and provide the owner with the best value he can get. This would provide them with economies of scale of information and process that are shared among all the suppliers involved. Each machine manufacturer taps into the collective expertise and data and drives up the overall quality of the machines. This type of coalition implies that the owner of the factory has to agree on only one "pack" of suppliers, and is then locked into this contract, and will not have full control over the terms and conditions eventually agreed upon. In addition to that, the owner can't break the contract with one of the suppliers in the consortium, should the need ever arise, to replace one

[16] Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.495.8766&rep=rep1&type=pdf
[17] Retrieved from https://ir.lawnet.fordham.edu/cgi/viewcontent.cgi?article=1013&context=ilj (pages 121-125)
[18] 42 CFR 420.302 - Requirement for access clause in contracts. (n.d.). Retrieved from https://www.law.cornell.edu/cfr/text/42/420.302#a (also References: 40-44 in the bibliography)
[19] Some advantages of multi-sourcing compared to prime contracting (n.d.). Retrieved from https://uk.practicallaw.thomsonreuters.com/1-545-5075?transitionType=Default&contextData=(sc.Default)&firstPage=true&comp=pluk&bhcp=1#co_anchor_a202224

machine part, by a better one, he is seen forced to accept, willy-nilly, the consortium between the suppliers, which suppliers have arrangements to work only together. The owner may always invoke the principle of negotiating again or terminating the contract, but he would end up with changing all the machines of his factory, with all the risks of increased costs that this change entails. Somehow, it might be a good advantage for the owner if he ends up the contract and comes up with a better idea than the one proposed by his supplier. This attribute suggests that there is a clear framework (which is not possible most of the cases) and loyalty and trust of the owner towards his suppliers, before even signing on the dotted line. Yet, the owner would have found an innovation by his own, they would be anyway bound by the Intellectual Property clauses of their stakeholder to accept that their machine supplier gets all the benefits. In the end, this is only a matter of, being the first, to break new ground with the latest technology or product. One is entitled to wonder what type of contract we would need with our suppliers and what it means to sign an engagement of collaboration, and being cooped up with it.

Mistakes do happen and are more likely to occur when different stakeholders cooperate.

III. **Confidentiality, data protection, ownership of documents, intellectual property[20]:** For the first alternative, the environment is well-structured and enables an unequivocal and unambiguous clause about ownership of documents and intellectual property. However, there is a provision concerning the confidentiality of processes and data protection. In the context of smart manufacturing, leveraging the capability of machines to interact with each other and surrounding systems, encompassing the ability to collect data and track the workflow of other machines and the performance metrics related to the processes in the factory, the owner and suppliers should take action, so as to ensure that only their data is secured. The shortcoming cannot be addressed in one clause of the contract since this new data provided was made possible only through the successful collaboration among many stakeholders, and also thanks to the intelligent machines that are learning by experience and going beyond what they were initially programmed for. In other words, we cannot take all the praise for the data analysis and results collected by these machines, first because when signing the contract, we don't know yet about all the potential data that can be gathered since technologies are evolving fast; and second, because not only one machine deserves the credit of what is reached so far, so all the machine designers have a right on the data collected. To close this gap, a technical solution would be appropriate to remedy the problem of confidentiality and data dissemination. The solution would be to encrypt

[20] ConsensusDocs Releases New Standard Short Contract Editions (ConsensusDocs :247-246-210)

every set of information, as it is done in blockchain with cryptography methods, authorizing only persons having a private key, to access to this information. However, we are again facing a new polarizing dilemma: The governance. Which stakeholder has enough authority to decide who can get or not the data and which information?

IV. **Work measurement Overall machines Efficiency**[21]**:** Smart machines boast efficiency we expect them to have. But working with different suppliers is double-edged sword which makes it a formidable attribute to consider for the three alternatives. In fact, one machine is communicating with a suite of other machines and are trying to complete the work together in line. Let's imagine that one of these machines is being more efficient than the others. Then, the others are overloaded and if they can't keep up with the same work pace, we would uncover new challenges such as bottlenecks for example, which lead to loss of productivity. Then, we would have to revamp the working stations and identify the source of inefficiency. It goes without saying that since machines are coworking and that each machine brings to the table what the other machine can't bring, we have to assess and estimate the overall efficiency because it is not enough to take each machine separately. But then whose job is it to assess the total efficiency, if each supplier is only providing one machine? Who should handle this risk and what type of contract is more adapted to enhance communication between the owner and his suppliers?

V. **Interoperability and compatibility between machines**[22]**:** The more collaboration there is between suppliers, the more chance to have profitable interoperability and compatibility between machines, speaking the same languages and using the same protocols. This is where things get tricky. We prefer that these machines collaborate rather than compete. If alternative 1 and 3 allow the compatibility between machines, not any supplier can get the credit of the data obtained, which is the fruit of their close collaboration. Thus, the data exchange will enable all players to obtain more information that it is suggested at the beginning.

We start witnessing the future of this machine-to-machine communication and conflicts we will have to resolve concerning confidentiality and intellectual property.

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[21] Intelligent Manufacturing in the Context of Industry 4.0: A Review. (n.d.). Retrieved from https://reader.elsevier.com/reader/sd/pii/S2095809917307130?token=302FB97E43825819432FD987DA5DE057A7419D728B4EB3B8FD4AF1B85724B640EFC6BB170AF2FDE21D2425B6A5C90577
[22] ConsensusDocs Releases New Standard Short Contract Editions (ConsensusDocs:200.2)

VI. **Use of information in case of cancellation/termination of the contract/ after completion of services or change of one of the suppliers:** No manufacturer can't deny having extra information, or real-time analytics about the performance of his own and the competitors' machines, and mainly the modern technology needed by his customer. It is no wonder that after terminating the contract and after installing his machines in the factory, he will still be likely to get some data via his machines. Even, if we cannot be sure how the supplier is going to use his holdings and if we cannot prevent him to get influenced or "inspired" by the competitors 'technology or the owner process, we can still strive to secure our data, with setting in forth, in a Data Processing Agreement[23] at least the following points:

- Ownership of documents, processes, and techniques
- Copyright of design, models, process, techniques between suppliers
- Use of documents, techniques or process after termination of the contract
- Owner's use of the machines and data after completion of services[24]
- Supplier's use of the data collected during the contract
- Supplier's use of the on-going confidential data collected after installing the machines and cancellation of the contract (data collected when offering additional services for example maintenance of the machine)
- Suppliers' use (deletion or retrieval) of the data collected from each other after the termination of data processing for the customer and obligations about data transfer

We have no choice but to ensure that any of the suppliers do not exceed the possession limit of the data in the contract obligations. Without a doubt, the list of clauses herein is less than being exhaustive and the terms shall be adapted to the specific legal situation and outlined in the agreements between the suppliers and the owner. (This DPA[25]at this moment can be a good start to draft the contractual clauses).

Limited to this use, we have protected the confidential data and intellectual property, but there is still one issue. Even though the owner or one of the suppliers could have found the same technical solution internally, it is now tied with the clauses to the other stakeholders and can't anymore defend its market against encroaching competition (that has after the end of the contract an equal or even better knowledge about the environment of production). This

[23] Data Processing Agreement. (n.d.). Retrieved from https://silktide.com/dpa/
Article 12. Termination. ConsensusDocs 245. Releases New Standard Short Contract Editions. (n.d.). Retrieved from https://www.consensusdocs.org/News/ViewArticle?article=ConsensusDocs-Releases-New-Standard-Short-Contract-Editions
[24] ConsensusDocs 247. Releases New Standard Short Contract Editions. (n.d.). Retrieved from https://www.consensusdocs.org/News/ViewArticle?article=ConsensusDocs-Releases-New-Standard-Short-Contract-Editions
[25] Inc., H. (2018, November 1). Data Processing Agreement. Retrieved from https://legal.hubspot.com/dpa

emphasizes even better the criticality of project and program management planning, process and procedures. Key components of the Project and Program Management scheduling, processes and procedures is to know how much we want to be bound from the launch of the project to other stakeholders. When acquiring machines or equipment, the owner does not know in advance about the upcoming technologies nor about how the current technologies would progress, so he might on the way find a better solution either by his own initiative or a one already reached by another competitor or supplier. Hence the need to plan how the owner could opt out from the current technology, and to establish some stringent procedures and contractual approach before any project of deploying machinery. Further, should any change occurs, both suppliers and owner have an exit door, while ensuring their data and intellectual property are secured.

Conflict of interests / Responsibility for compliance / Resolution of conflict process[26]:

Based on the premise that the suppliers are only promoting the owner productivity and that their top priority is the owner's satisfaction, no conflict should ever happen, nor this common interest should be altered. An interesting irony is when suppliers have found in the competitor's technology a better solution to improve their own machine. A conflict of interest may arise concerning the handling of the information provided by the smart machines when it starts to be interesting for both players to appropriate the idea for their behalf.
An ethical clause about conflict resolution process would preempt the buildup of the conflicts before "each party waives their right to be heard in a court of law.[27]

Step 3: Ranking of the Feasible Alternatives using a QUALITATIVE method - Outcomes and cash flows for each alternative

Attribute	Alternative 1: Clear contracts signed without a consortium	Alternative 2: No agreement	Alternative 3: Consortium between all the suppliers
I - Security of transmission / Encryption / Access requirements	The owner is the only one who can decrypt all the information on the different machines.	Worse: Information is transmitted in a non-agreed way.	Better
II - Opportunities for cooperation between suppliers and higher quality of services and products/innovation	Medium	Worse: No Cooperation	Better

[26] References 17-18-19 in the Bibliography and consensusDocs
[27]" Article 13. ConsensusDocs 245. Releases New Standard Short Contract Editions. (n.d.). Retrieved from https://www.consensusdocs.org/News/ViewArticle?article=ConsensusDocs-Releases-New-Standard-Short-Contract-Editions

III - Confidentiality and copyrights of methods, processes, systems, design - Preservation and protection of data - Intellectual property clauses and ownership of documents - Clarity of contractual terms	Medium	Worse	Better
IV- Work measurement Overall machines efficiency	Worse	Worse	Better
V- Interoperability, and compatibility between machines-data exchange	Medium	Worse	Better
VI- Use of information in case of cancellation/termination of the contract/ after completion of services or change of one of the suppliers	Better	Medium: Termination or cancellation is possible, but there is a risk that a supplier steals the design or techniques from other manufacturers to improve his own machines	Worse: Changing one of the suppliers is not possible anymore
VII- Conflict of interests / Responsibility for compliance / Resolution of conflict process	High	Very high	High
Dominance	Maybe	No	Yes

Table 2 - Non-Compensatory model technique: Qualitative Analysis [28]

Step 4: Selection of the Criteria to accept the Alternative Solution -

We chose the following colour code for the qualitative analysis of the table:

- The green represents the alternative that has the most positive impact.
- The amber indicates that the attribute has a higher risk than the green one and that there are problems to consider.
- The red is the alternative that has the worst impact or highest risk.

So, our minimum acceptable criterion is to have the minimum red and amber coloured attributes cells for the right alternative we would accept.

[28] By Author. For more information, see Multi-Attribute Decision Making method in 10.3.3.7 http://www.planningplanet.com/guild/gpccar/managing-change-the-owners-perspective

In our case, we can observe that alternative two is the poorest, which has six red and two amber coloured attributes, but still a promising alternative for us (we will develop that on the findings). Alternative three is dominant and therefore accepted.

We then chose the additive weight technique, to have a more quantitative analysis:

Attributed score for each colour	0,33	0,66	1

Attribute	Alternative 1	Alternative 2	Alternative 3
I	1	0,33	1
II	0,66	0,33	1
III	0,66	0,33	1
IV	0,33	0,33	1
V	0,66	0,33	1
VI	1	0,66	0,33
VII	0,66	0,33	0,33
Sum	4,97	2,64	5,66

Table 3 – Quantitative Analysis [29]

We can clearly observe that alternative 1 and alternative 3 have close quantitative weights, even though alternative 3 was the best, five times among 7.

So, the current ranking of our alternatives, from the best to the worst, is the following: Alternative 3 → Alternative 1 → Alternative 2.

FINDINGS

Step 5- Summarize, showing the relative rank order of our choices

We decided to use the additive weighting technique, by ranking the attributes, normalizing the weights and dividing our score by this norm. For this method, the perfect option would have a score of 1.00, and anything less than 1.00, means that the solution would need some other special trade-off to find a middle ground.

[29] By Author

	Step 1	Step 2			Alternative 1		Alternative 2		Alternative 3	
Attribute	**Relative Rank**	**Normalized weight (A)**			**(B)**	**(A)x(B)**	**(C)**	**(A)x(C)**	**(D)**	**(A)x(D)**
Data Security / Access requirements	2	2/28	=	0,07	1,00	0,07	0,33	0,02	1,00	0,07
Cooperation (Quality & innovation)	6	6/28	=	0,21	0,66	0,14	0,33	0,07	1,00	0,21
Confidentiality, IP, ownership	1	1/28	=	0,04	0,66	0,02	0,33	0,01	1,00	0,04
Overall efficiency	4	4/28	=	0,14	0,33	0,05	0,33	0,05	1,00	0,14
Interoperability	5	5/28	=	0,18	0,66	0,12	0,33	0,06	1,00	0,18
Use of data after contract termination	3	3/28	=	0,11	1,00	0,11	0,66	0,07	0,33	0,04
Conflict of interests Resolution	7	7/28	=	0,25	0,66	0,17	0,33	0,08	0,33	0,08
Sum	28	Sum	=	1	Sum =	**0,67**	Sum =	**0,37**	Sum =	**0,76**

Table 4 - Additive Weighting Technique [30]

Using the table above and the Additive Weighting Technique, we can generate a Ratio Scale.

[30] By Author. For more information, see figure 14 COMPENSATORY MODEL Technique 2: Additive Weighting Technique from the GUILD OF PROJECT CONTROLS COMPENDIUM and REFERENCE (CaR) | Project Controls - planning, scheduling, cost management and forensic analysis (Planning Planet). (n.d.). Retrieved from http://www.planningplanet.com/guild/gpccar/managing-change-the-owners-perspective

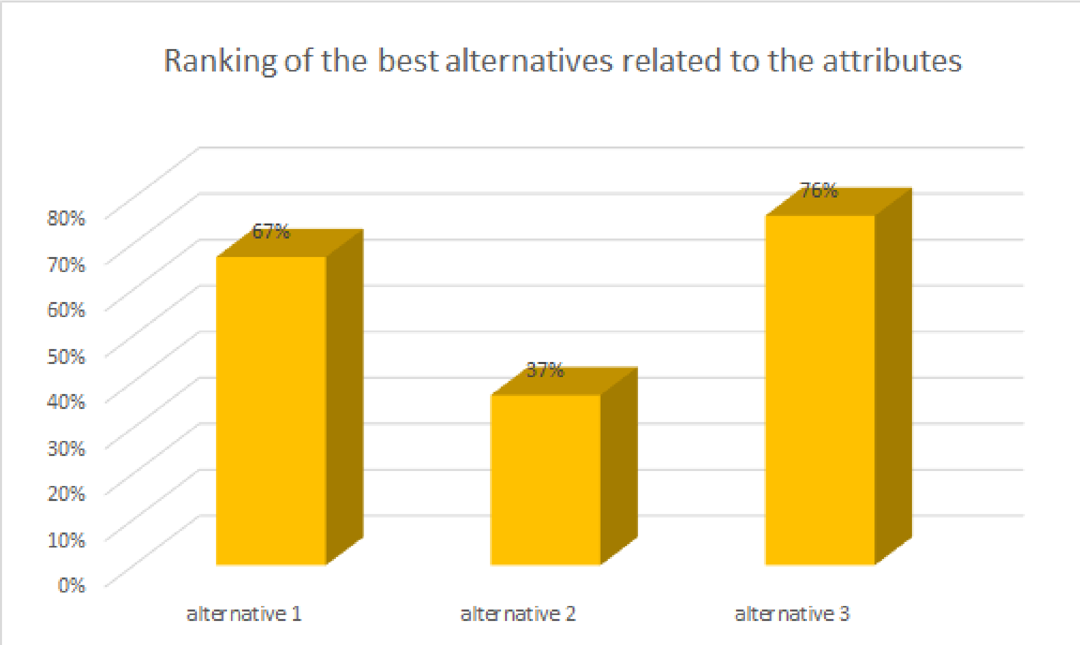

Figure 4- Ranking of the best alternatives by Percentage [31]

Step 6- Applying the criteria identified in Step 4, and explain the recommended choice

Now we can conduct a Pareto analysis to justify the alternative 3. "Pareto Analysis is a statistical technique in decision-making used for the selection of a limited number of tasks that produce a significant overall effect."[32]

We decided to use the previous steps (4-5) to conduct a Pareto Analysis for each one of our alternatives separately, considering that the overall efficiency of work, being our main concern and criterion for choosing the option. We can compare the results, presented below:

[31] By Author.
[32] Pareto Analysis Step by Step. (n.d.). Retrieved from https://www.projectsmart.co.uk/pareto-analysis-step-by-step.php

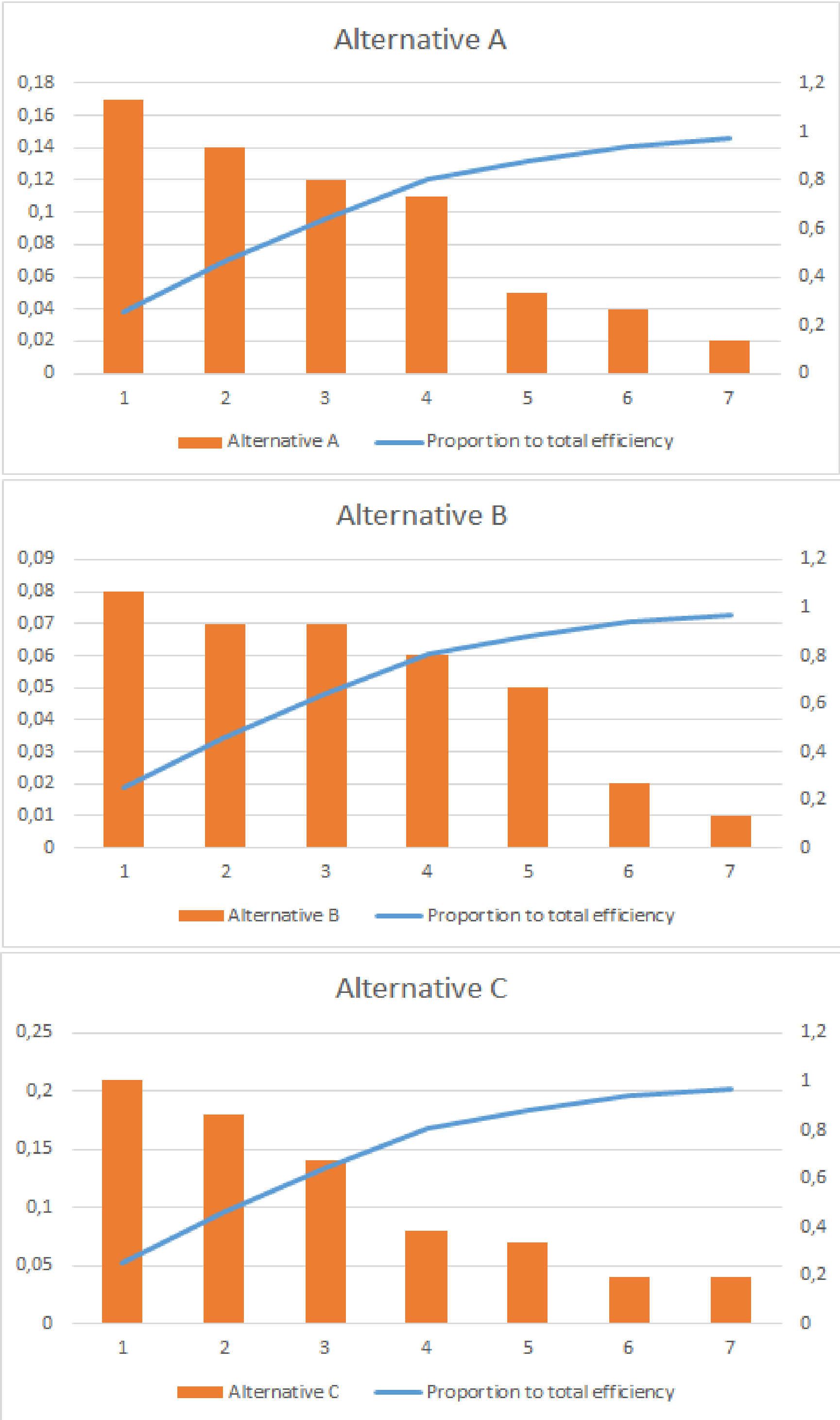

Figure 5- Pareto analysis for each alternative in proportion to efficiency [33]

[33] By Author.

We can notice that we reach 80% with already the two first attributes in alternative 3. Which means that these attributes are caused by 20% of the rest of the attributes, which confirms that alternative 3, is better than alternative 1 and 2, if we consider Data Security, confidentiality, ownership and Intellectual Property, and conflict of interests due to the use of data after the contract termination, our main issues. Whereas, cooperation and creating a consortium, with good interoperability between the machines to control the overall efficiency, represent the primary solution.

Step 7- Demonstrate that the recommendation is a good one (General Pareto Analysis)

This method could give us a hint about the best alternative if we consider the overall efficiency of the machines the main concern of the owner in the factory (which was a subjective choice). But let's use now a more general analysis[34] to identify the main criteria to consider when choosing the right alternative.

The general methodology for a Pareto Analysis is to identify problems for each attribute and then count the problems for each attribute and sort the attributes by importance (considering the one having more problems than the others).

We can regroup and summarize the problems encountered with each attribute and some potential solutions in the following table:

Attributes	Problems [35]	Solutions [36]
Data Security	Data can be collected by all the suppliers	- Network Segmentation - Intermediary systems - Hardware security modules with encryption or tokenization - Authentification with a key and access controls - Risk assessment and monitoring the problems - "Attack Surface Reduction"
	Data can be hacked	
	Access rights are required	
	The more connectivity, the more chance the network can be hacked We don't first think about a cyber-attack when something goes wrong	

[34] Applying the Fishbone diagram and Pareto Principle to Domino. (n.d.). Retrieved from https://www.ibm.com/developerworks/lotus/library/pareto/
[35] Rising to the Industry 4.0 cybersecurity challenge. (2018, February 21). Retrieved from https://www.theengineer.co.uk/industry-4-0-cybersecurity/
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[36] Industry 4.0 and cybersecurity. (n.d.). Retrieved from https://www2.deloitte.com/insights/us/en/focus/industry-4-0/cybersecurity-managing-risk-in-age-of-connected-production.html

	Time and costs to detect a data security vulnerability	- Machine learning - Artificial Intelligence - Cloud - Regulation, laws, and standards concerning protection - Open source - Using a Blockchain - Governance
Interoperability	Machines can't communicate with each other	
	Machine learning and process analysis and a decision made in real-time	
Cooperation	The suppliers can't work together which leads to conflicts	
	Lack of innovation when suppliers are not competing against each other	
	Manufacturers appropriation of other's ideas	
	The owners and suppliers are tied by the contract engagement and loyalty towards each other and not the competitors	
Use of data after contract termination	Data can be used after the contract cancellation	
	Industrial Technological espionage	
	Sabotage	
Confidentiality, ownership, Intellectual Property (IP)	There is no ownership / IP with the data provided by the mutual analysis and collaboration of smart machines or	
	Data dissemination	
Conflicts of interest	Machine efficiency VS overall machines efficiency, productivity, and performance	
	Governance	
	Ownership and appropriation of the data provided by the machines	
Work measurement overall machines Efficiency	The machines might not perform well altogether because ones are better	

It is even apparent in this table that most of the problems can be considered as a solution for other issues.

The next step is to sort the attributes causing the most problems in descending order.

Total number of problems	20		100%
Data Security	5	5/20*100	25%
Interoperability	2	2/20*100	10%
Cooperation	4	4/20*100	20%
Use of data after contract termination	3	3/20*100	15%
Confidentiality, ownership, Intellectual Property (IP)	2	2/20*100	10%
Conflicts of interest	3	3/20*100	15%
Work measurement overall machines Efficiency	1	1/20*100	5%

Then we calculate the cumulative weights as below:

Attribute	% of Total	Computation	Cumulative
Data Security	25%	25	25
Cooperation	20%	25+20	45
Use of Data after contract termination	15%	15+45	60
Conflict of interests	15%	60+15	75
Confidentiality, ownership, IP	10%	10+75	85
Interoperability	10%	10+85	95
Overall Machines Efficiency	5%	5+95	100

It was easier for us to code the weights with the tool Anaconda, using Jupyter Notebook[37], to have the cumulative weights as shown in this code and obtain the following Pareto chart considering the importance of the attribute by the occurrence of problems.

[37] Code available in Pareto Chart – Snakegourd. (n.d.). Retrieved from https://snakegourd.wordpress.com/tag/pareto-chart/
NB: There is one package called paretochart, that we can download on GitHub https://github.com/tisimst/paretochart used with python2 and previous versions. So, in case we want to use this package with python3, we have to change the source code in paretochart.py, with respecting the indentation, the lines 162-168 by the following structure : t.has_key(x) becomes: key=x if key not in t , so that Anaconda Python3 can support it. The result can be reproduced following this link too: Pareto chart. (n.d.). Retrieved from https://pypi.org/project/paretochart/

```
from matplotlib import pyplot as plot
import numpy as np
preference = ({'Data Security':5,'Data use_contract termination':3,'Conflict of interests':3,
              'Cooperation':4,'Confidentiality, ownership, IP':2, 'Interoperability':2,
              'Overall Machines Efficiency':1 })

# sort preference in descending order
weights, labels = zip(*sorted(((pref,genre) for genre,pref in preference.items()), reverse=True))

for i in weights:
 cumu_1 = weights[0]
 cumu_2 = weights[1] + cumu_1
 cumu_3 = weights[2] + cumu_2
 cumu_4 = weights[3] + cumu_3
 cumu_5 = weights[4] + cumu_4
 cumu_6 = weights[5] + cumu_5
 cumu_7 = weights[6] + cumu_6
cumu_weights = [cumu_1,cumu_2, cumu_3, cumu_4, cumu_5, cumu_6, cumu_7]
```

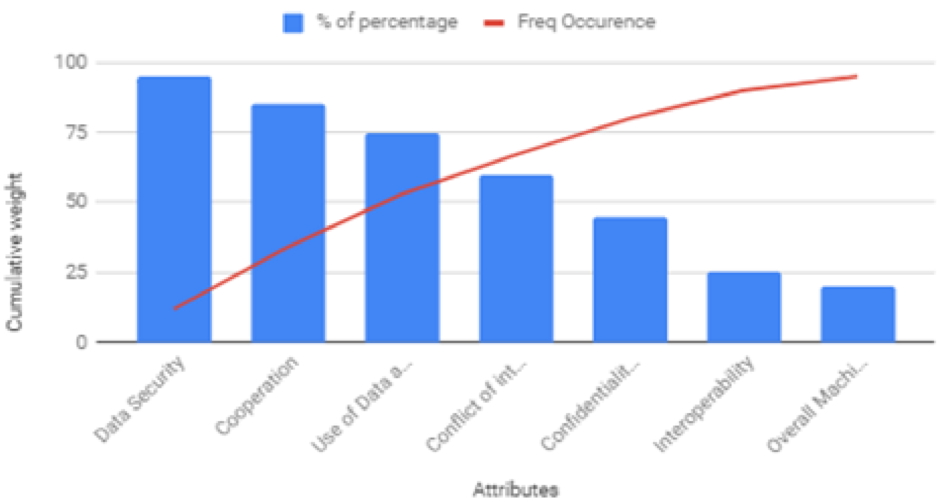

Figure 6 - Pareto analysis [38]

In the model studied, we can see that the five first attributes represent 80% of the problems and that the rest (20% represent the solution). Those risks could be identified and ordered based on the frequency of occurrence of the problems and therefore, we can propose to invert the graph as in the code below, taking into consideration the same cumulative weights (found in the table step 7) which represent the total number of problems (20) as being 100%, and if we reduce by 80% the problems by applying 20% of the attributes of alternative 3 (which are data security, cooperation), regrouping the 5 first attributes as 80% of the problems and the 2 left attributes as 80% of the solution, we can obtain the following graph:

[38] By Author. More information about the Pareto analysis could be found in the: GUILD OF PROJECT CONTROLS COMPENDIUM and REFERENCE (CaR) | Project Controls - planning, scheduling, cost management and forensic analysis (Planning Planet). (n.d.). Retrieved from http://www.planningplanet.com/guild/gpccar/risk-opportunity-monitoring-and-control

```
pareto(data, labels, limit=0.80, axes=axes[0, 1], limit_kw={'color': 'y'})
plt.title('After implementation', fontsize=20)

fig.canvas.set_window_title('Pareto Analysis')
plt.show()
```

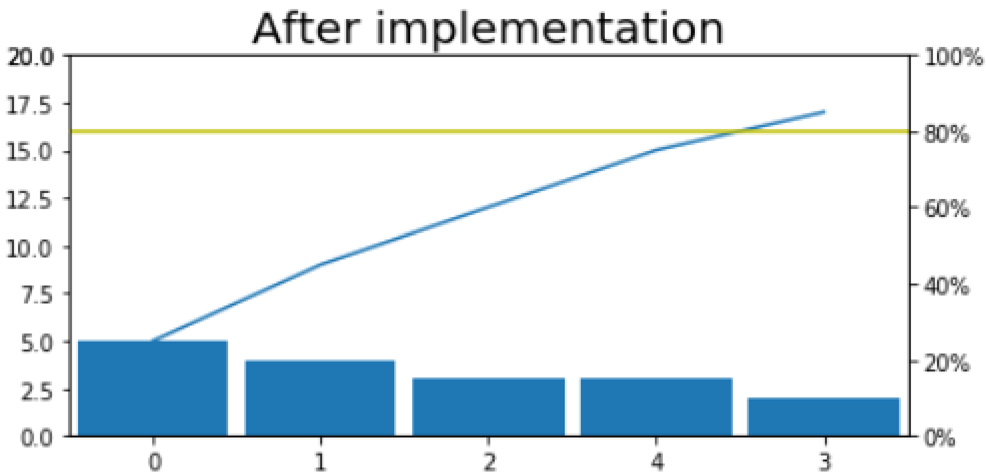

Figure 7- After implementation Pareto Chart [39]

It becomes clear from this analysis that Alternative 3, where the different stakeholders are in the consortium is the safest solution. Therefore, we recommend this option.

To complete our analysis, we drew up the force field analysis[40], to show also the drawbacks of this alternative.

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[39] By Author.
[40] Force Field Analysis Analyzing the Pressures For and Against Change. (n.d.). Retrieved from https://www.mindtools.com/pages/article/newTED_06.htm

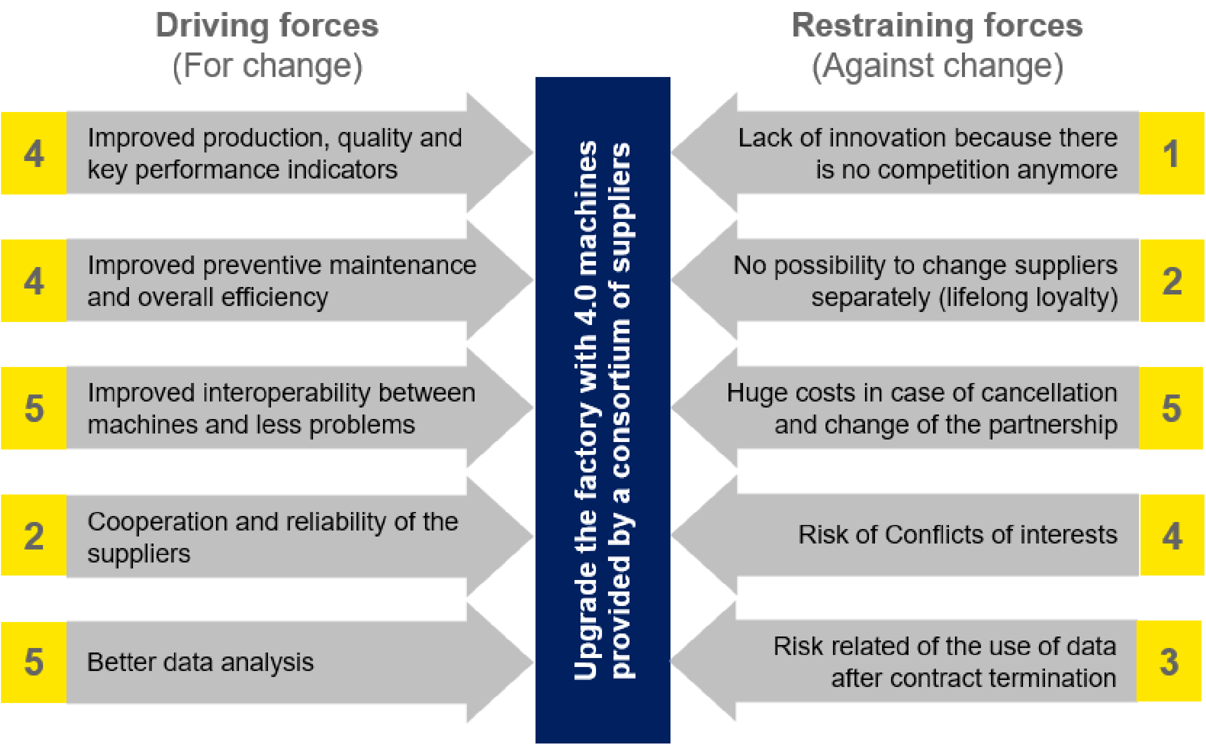

Figure 8- Force field Analysis of alternative 3 [41]

CONCLUSION

The purpose of this paper was to present a clear method of Project and Program Management, by defining the best contractual approach to have between an owner of a factory and the machines' suppliers in the context of industry 4.0. In order to manage these processes, we identified three contractual approaches and assessed them, by focusing on different criteria that are strategic for the owner and the manufacturers.

Through our analysis, we used the non-Compensatory model technique to have a qualitative Analysis and then we tried a more quantitative approach by using the additive weights technique, which allowed us to conduct a Pareto analysis and conclude by the force field analysis of the chosen option.

We came to the conclusion that the best solution for the owner to avoid the loss of data and ensure confidentiality and improve the production performance, would be to choose a group of suppliers that are already working together and forming a coalition or a consortium, and that can offer a complete service and products, including better-managed maintenance, and more machines which are totally compatible with one another; thus, ensuring hopefully, to decrease costs, reduce the manufacturing time and improve the performance in projects.

[41] By Author.

FOLLOW ON RESEARCH

All the findings have shown that choosing a consortium is favourable for an owner and can also be advantageous for suppliers. However, we may ask ourselves, if this would be a new form of business organization, where there is no place for young and small companies. Does everyone need to put themselves in a consortium/holding? Would there be any place for innovation in a small start-up? Does a young start-up have to be bought or adopted by a holding company as soon as they find a new proven technology/concept/process? And how to prove an innovative concept if you cannot enter the production loop? Would industry 4.0 lead to the decline or deceleration of the innovation process? This means that we would have some large holding companies of suppliers who share the whole market and that there wouldn't be any place for little innovators in small startups.

Then, if even this solution is risky, we may come back to the alternatives proposed before in the methodology and try to make them more acceptable. Remember that the problems with these alternatives were mainly about security and confidentiality. So what better way than removing the concept of confidentiality? The key would be to carry out more encryption, by adopting two communication codes: The first one between machines, that would be understandable by all, but conveying only a limited amount of information. And a second one: a private and secured code, conveying all the secrets of the machine, but which can only be read by the supplier of the machine itself. Should we be then concerned about the technological and industrial espionage? Is this the beginning of a cold war between technology providers? It is evident that Alternative 2 is for the moment the least secure and least protected, but can't we also think about migrating to open-source machines where the supplier offers simple basic hardware and everyone can contribute to improving it in Open-source? We are afraid of data spreading. So again what would be better than removing the professional secrecy and the competition between suppliers? This would ensure some complementarity between technology and software packages providers. The example has already begun with open labs, prototyping with 3D printers in open source. But again, this option can only offer innovation niches for short periods, in small markets, until the technology is unveiled and becomes known by everyone, or protected and chargeable, so would this model be sustainable for all industrial products?

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About the Author

Sonia Bouden

Tunisia, France

Sonia Bouden is a final year double-degree student, studying entrepreneurial and industrial engineering at ITEEM-Centrale Lille, specializing in Production Systems Engineering and preparing a Master degree at SKEMA Business School in Project and Program Management and Business Development.

Great networker, versatile student, with strong organisational and interpersonal skills, Sonia has been involved in many associations, projects and clubs, that allowed her to run interdisciplinary projects and acquire skills in leadership and project management.

She was member of the school board of directors, delegate at Centrale Lille and SKEMA, path career finder at SKEMA, responsible for the Centrale Lille's female football club, president of the association of Arab students and integration of foreign people at Centrale Lille and in charge of the good relationships with industrials, partners of the school.

She is passionate about horse riding, Rock and Roll (dance), 3D printing and is highly interested in innovation in industry linked to 3D printing and other new technologies including Blockchain, IoT, mainly in healthcare, sustainable development and aeronautics.

Sonia has an experience in production and lean management and is closely plugged in to French, German and Tunisian industries. She is keen on working on subjects related to industry 4.0 and smart manufacturing. Through her 16-month internship experience in France, Germany and Tunisia (at EY, Airbus Operations GmbH, Health for development, Furet du Nord) and 4-year experience from school projects in partnership with companies (Decathlon, Adeo, Greenyard, Velux, GrandsEnsemble), she has acquired a good insight on the different companies cultures and a good expertise on different sectors.

Sonia can be contacted at bouden.sonia.s@gmail.com