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<td>AR</td>
<td>Augmented Reality</td>
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<tr>
<td>DSS</td>
<td>Decision Support System</td>
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<td>EC</td>
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<td>EU</td>
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<tr>
<td>SWOT</td>
<td>Strengths Weaknesses Opportunities and Threats</td>
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<tr>
<td>WIPO</td>
<td>World Intellectual Property Organisation</td>
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<tr>
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EXECUTIVE SUMMARY

This document (named D7.1) represents the first update of the official deliverable D7.1, released in December 2015, whose main scope was to give a description of the technologies that are the objective of the development in the SatisFactory project and a first description of the destination market.

The scope of this document is to give an updated picture of the market, which includes market segmentation, a classification of software/hardware solutions now available as commercial components as well as an insight about some known key Research projects still in progress. Furthermore, the exploitation plan has been modified according to the developments in M13-M24 of the project.

The main updates can be summarized as in the following list:

1. An improved version of the report analysis of the market by industry segment and geographic region, performed during the second year of the project; more market target segments and different use of the technologies have been identified; as consequence, a more clear view of the user perceived and real customer needs has been obtained.
2. The Satisfactory Technologies has been grouped in “Bundles” in order to be more efficient and more effective in the exploitation activities.
1 INTRODUCTION

Europe leads in many manufacturing sectors from automotive to pharmaceuticals and many European players are global leaders in advanced manufacturing and also strong in many innovative high-quality services. The market analysis confirms that EU businesses, and in particular SMEs, are aware about the need of embracing the digital era to meet the new market opportunities.

Nevertheless, according with the recent declarations of Ms Lowri Evans, Director-General for the Internal Market, Industry, entrepreneurship and SMEs, spoken at the Science/Business Network conference on “The future of manufacturing: Industry 4.0”, two of four businesses in Europe do not use any advanced digital technology. In the manufacturing sector, one business out of two has never used any advanced manufacturing technology.

So, a huge potential market exists for new technologies enabling the digital transformation required for manufacturing enterprises.

In this framework, the SatisFactory project aims to develop a new holistic approach to the organization of work within a manufactory industry context. A significant part of the research activity will be spent in the development of a suite of software tools and innovative hardware devices with the objective of transforming this vision in something viable for the today’s and tomorrow’s industry. The focus is in creating attractive workplaces for the factories and the workers of the future. The tools and concepts are applicable also in the current workplaces and processes.

SatisFactory is a complex solution that includes several components based on various technologies that will target more sectors of the manufacturing industries and will be the object of use and commercialization by the project partners. This complexity made the marketing analysis and in particular the competition analysis, very difficult. In fact, the Product that will result from the development activities is not just the sum or the composition in a single bundle of different technologies and tools; many possible combination of technologies have to be considered, targeting different typologies of customers (for size, geographic area, maturity of the processes etc.).
2 Market Analysis

2.1 Business Environment

The evolution of the market during the 2016 has been characterized by a strong growing interest for the so-called Industry “4.0 Revolution” that is becoming more and more a popular word in the world of industry.

This interest is also pushed by the financial support of the governments. For example, in order to react to the lack of investments in the Industry 4.0 and encourage the growth, the Italian Government has just announced a plan that will see investments of € 13 billions in the next 3 years. These investments will be performed by means of provision of different types of tax incentives which should lead to an increase in 2017 of investments by private companies in innovations of € 10 billion. Such amount is higher than the investment of half a billion dollars planned by the US.

The keywords in the current vision of Industry 4.0 includes: IOT, Big data & Advance Analytics, Additive manufacturing, Collaborative Robots, Augmented & Virtual Reality.
SatisFactory aims to provide high technologies and associated services to manufacturers for improved factory efficiency and employee well-being. Describing the context of the manufacturing industry in Europe (especially novel ICT for industry) is a key step for setting the framework in order to perform an in-depth market analysis. Section 3.1 presents a macro level analysis of the main economic, political and technological trends impacting the marketing potential of SatisFactory’s products.

In this section, “industry” refers to the manufacturing sector (i.e. industries providing added value through the transformation of materials into products) and excludes mining, construction and energy.

Potential customers of SatisFactory products are companies with highest innovation potential, investment capacities and with needs correlated to our technologies.

### 2.1.1 Economic trends in the European industry

#### 2.1.1.1 The importance of the manufacturing industry in Europe

In the European Union, the industrial sector is important to the EU economy and remains a driver of growth and employment. In Europe, nearly one in ten businesses is classified as manufacturing, with a total of around 2 million manufacturing companies, accounting for 33
million jobs. The manufacturing industry accounts for around 15\% of EU28’s GDP and for over 80\% of exports. However, the EU is still far from reaching the objective to increase the share of the industry in GDP up to 20\% by 2020. With an increasingly competitive global economy, the economic future of the EU is intertwined with its capacity to innovate and to sustainably develop its manufacturing sector.

The major bulk of statistics in the first edition of this paper was based on the European Competitiveness Report of 2014. At present, a more recent release of the same document is not available, still some data have slightly changed. While the overall number of manufacturing companies in EU and the export share of EU manufacturing industry present the same figures, manufacturing industry GDP share, employment rate, industrial output and production do not. In detail:

I. EU GDP share of manufacturing industry has decreased during 2014 from 15.3\% to 15.1\%, touching 15.0\% in 2015Q4 (Eurostat)

II. EU Employment growth rate for manufacturing industry has increased in 2015Q4, with respect to the same quarter of the previous year, 0.5\% (Eurostat)

III. EU industrial output increased roughly 1.8\% in 2015Q4 with respect to the same quarter of the previous year (Eurostat)

IV. EU industrial production has increased, during August 2016 (latest data available), 0.8\% with respect to 2014Q4, but has registered a sharp fall during 2016 (-1.7\% fall since January 2016)

2.1.1.2 The impact of the economic crisis on the manufacturing sector

As of 2014, the economy of the manufacturing sector has not fully returned to its pre-crisis level. The relative contribution of industry to the EU economy has declined from 16.5\% in 2008 to 15.3\% in 2014. The overall EU28 manufacturing output decreased by 10\% in 2014 compared to 2008. The de-industrialisation process is partly due to re-location of manufacturing activities in countries with lower labour cost, notably Asia. The health of the manufacturing sector varies considerably across countries. During the 2008-2014 period, a few member states have seen a positive growth of the manufacturing production (namely Poland, Slovakia, Romania, Estonia), while others have seen a stagnation (Belgium, Austria, Czech Republic, Netherlands, Latvia, Lithuania, Germany). In a majority of countries, production has dramatically decreased (by more than 20\% in Cyprus, Greece, Spain, Finland, Italy, Sweden, Croatia).
The situation varies across sectors. When comparing productions in 2014 with that of 2008, the most affected sectors are: Clothing, Tobacco, Furniture (-35% to -25%); Textile, Electrical, Petroleum/Coke, Electronic, Machinery, Basic Metal, Metal Products (-25% to -15%); Motor Vehicles, Rubber/Plastics, Beverage, Chemical (-15% to 0%). At the same time, production in Food, Other transport equipment, and other manufacturing grew slightly (0% to 15%), and the Pharmaceutical sector grew significantly (more than 15%). Globally, emerging countries such as Brazil, Russia and China are not exempt from the global economic downturn. Despite grimmer expectations, however, in October Chinese factories activity rose to the highest level in more than two years, adding to recent signs that the world's second-largest economy is stabilizing. In this late 2016, China is also on the news for a major debate taking place in Europe, regarding the “market economy status” that the EU Parliament should recognize to China in the coming months. Such recognition would compel European states to repeal tariffs against Chinese goods, favouring free trade, while at the same time exposing European manufacturers to a even harsher competition with Asian counterparts. However, it is interesting to note that in general, European manufacturing industry has started to recover in 2014. In a majority of sectors, production in 2014 is higher than it was in 2013, as shown in the figures below.

An interesting trend is that the evolutions in production seems less and less correlated with jobs creation, with employment in EU manufacturing declining steadily since 2000 (-20% between 2000 and 2014).

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3 Source: EC, European Competitiveness Report 2014 (based on Eurostat and OECD)
The manufacturing industry shows slight signs of economic recovery (the overall production is back to is early 2000s level). This upward trend has led to improved market sentiment and business confidence, favourable for investment and innovation.

2.1.1.3 **Investing in ICT technologies for factories will benefit the economy**

Despite this context of prolonged crisis, some companies are gaining new markets thanks to R&I investment oriented toward new products, services and emerging technologies. In

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4 Source: EC, European Competitiveness Report 2014 (based on Eurostat and OECD)
particular, investing in digitalization of industrial production line will enable to improve both factory efficiency and workers’ safety. As revealed by Atomico, an investment firm, in a document published this year ("The state of European Tech", Atomico & Slush, 2016), European corporations are increasingly active in tech industry: in 2016 alone at least 2.7B$ in committed capital were dedicated to CVC funds, more than 2/3 of the aforementioned European corporations have made direct investment in tech companies, more than 1/3 have outright acquired a tech company and 40% of them run active tech focused accelerator programs. Strategic development of ICT technologies for manufacturing is called “Industry 4.0”, i.e. the fourth industrial revolution, mainly based on digitalization. Industry 4.0 may help to reverse the past decline in industrialisation and increase manufacturing added value.

Industry 4.0 can deliver estimated annual efficiency gains in manufacturing of between 6% and 8%. The Boston Consulting Group predicts that in Germany alone, Industry 4.0 will contribute 1% per year to GDP over ten years, creating up to 390 000 jobs. Globally, one expert estimates that investment on the Industrial Internet will grow from US$20 billion in 2012 to more than US$500 billion in 2020 (albeit with slower growth after that date), and that value added will surge from $US23 billion in US$1.3 trillion in 2020.

(Source: EUROPEAN PARLIAMENT RESEARCH SERVICE (EPRS), Industry 4.0)

The EC publishes yearly reports (European Competitiveness Reports) highlighting internal weaknesses hampering economic growth of industry in Europe. According to the reports, too low investment in research and innovation hold back the necessary modernisation of the EU industrial base and hamper future EU competitiveness. On the other hand, the EU’s competitive strength has always been built on a solid and predictable institutional environment, quality infrastructure, a strong technological knowledge base and a healthy and educated labour force.

An exhaustive picture regarding the state of the art of Industry 4.0 in Europe, North America and Asia has been published in a 2015 report by PwC, an investment firm: “Industry 4.0: Building the digital enterprise”. According to this, a certain number of big European companies are already implementing massive digitization in their processes. The list includes BASF, Bosch, Daimler, Deutsche Telekom, Klöckner & Co., and Trumpf. The momentum is rapidly growing elsewhere as well, particularly in the United States, Japan, China, the Nordic countries, and the United Kingdom. Such influential global industrial behemoths as Siemens and GE have fully embraced the approach. In the same report, PwC surveyed more than 2,000 companies from 26 countries in the industrial production sectors, including aerospace and defence; automotive; chemicals; electronics; engineering and construction; forest products, paper, and packaging; industrial manufacturing; metals; and transportation and logistics. In this global Industry 4.0 survey, one-third of the respondents said their company had already achieved advanced levels of integration and digitization, and 72 percent expected to reach that point by 2020.
Respondents were asked: "How would you classify the current level of digitization and integration [in operations, supply chain, and related activities] in your company? What levels are you expecting in the next five years?"

<table>
<thead>
<tr>
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<tr>
<td>45% Electronics</td>
<td>77%</td>
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<tr>
<td>32% Aerospace and Defense</td>
<td>76%</td>
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<tr>
<td>35% Industrial Manufacturing</td>
<td>76%</td>
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<tr>
<td>32% Chemicals</td>
<td>75%</td>
</tr>
<tr>
<td>38% Forest Products, Paper, Pkg.</td>
<td>72%</td>
</tr>
<tr>
<td>28% Transportation and Logistics</td>
<td>71%</td>
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<tr>
<td>30% Engineering and Construction</td>
<td>69%</td>
</tr>
<tr>
<td>41% Automotive</td>
<td>65%</td>
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<tr>
<td>31% Metals</td>
<td>62%</td>
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Figure 5: Industry 4.0 adoption by sectors, exhibit 1

This momentum reflects expectations of rapid payoffs in business results. An overwhelming majority (86 percent) of the survey respondents said that on the basis of their experience to date, they expected to see both cost reductions and revenue gains from their advanced digitization efforts. Nearly a quarter expected those improvements, in both cost savings and revenues, to exceed 20 percent over the next five years. Making Industry 4.0 work requires major shifts in organizational practices and structures. These shifts include new forms of IT architecture and data management, new approaches to regulatory and tax compliance, new organizational structures, and - most importantly - a new digitally oriented culture, which must embrace data analytics as a core enterprise capability. In the PwC study of Industry 4.0, the most commonly cited difficulty in building an analytical capability was the lack of people with the expertise to conduct the analysis. With 5 of world’s top 10 Computer Science Institutions, an average of 1 in 5 MBA graduates from top-ranked business schools entering

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5 Source: Industry 4.0: Building the Digital Enterprise, PwC
tech and 4.7M of professional developers, Europe seems to have all the right cards to overcome this obstacle.

2.1.2 Policy plans supporting the factory of the future (macroeconomic governance)

The SatisFactory project will take advantage of the policy plans supporting the fourth industrial revolution (Industry 4.0) at European and national levels.

2.1.2.1 EC industrial policies

The EU supports industrial change through its industrial policy and through research and infrastructure funding. In 2012, in response to the decline of the relative contribution of industry to the EU economy, the European Commission set a target that manufacturing should represent 20% of total value added in the EU by 2020. Whilst some observers find this goal overly ambitious revolution, Industry 4.0, which could boost the productivity and value added of European industries and stimulate economic growth. As part of its new Digital Single Market Strategy, the European Commission wants to help all industrial sectors exploit new technologies and manage a transition to a smart, Industry 4.0 industrial system. (Source: EUROPEAN PARLIAMENT RESEARCH SERVICE (EPRS), Industry 4.0: Digitalisation for productivity and growth, September 2015)

The European Union regularly issues reports on the manufacturing industry in Europe and other publications related to ICT R&I for improving the productivity and safety of the production line, notably, Industrial Policy Communications, European Competitiveness Reports and Member States’ Competitiveness Report issued in the context of the European Semester (see: section 4 on literature). A summary of the EC industrial policy can be found on the following webpage: http://ec.europa.eu/growth/industry/policy/index_en.htm

Fostering growth and competitiveness and achieving the goals of the Europe 2020 agenda are part of top priority for the EC and EU Member States. European industry will need to capture the potential for productivity and growth that Industry 4.0 appears to offer in order to remain competitive.

The SatisFactory consortium is liaising with European manufacturing organizations in order to promote the project technologies and potentially to find relevant information for the market analysis and exploitation strategy. In particular, SatisFactory has established synergies with the two following organisations:

- The European Factories of the Future Research Association (EFFRA) is a non-profit, industry-driven association promoting the development of new and innovative production technologies. MANUFUTURE technology platform and key industrial associations established jointly the EFFRA in order to promote and support the implementation of the ‘Factories of the Future’ public-private partnership.

- The Intelligent Manufacturing Systems (IMS) is an industry-led, international business innovation and research and development (R&D) program established to develop next generation of manufacturing and processing technologies through multi lateral collaboration. It provides global services to institutions from the supporting regions including the European Union, Mexico and United States of America and is a premier sponsor of the World Manufacturing Forum (WMF) event.
2.1.2.2 **National industrial policies**

EU Member States sponsor national initiatives related to digital manufacturing such as:

- **Industrie 4.0** is the German strategic initiative on advanced manufacturing solutions. The term “Industry 4.0” originates from the German government’s programme for creating smart factories presented at Hannover Messe (industrial fair) in 2011. The Chancellor Angela Merkel defined Industry 4.0 as “the comprehensive transformation of the whole sphere of industrial production through the merging of digital technology and the Internet with conventional industry”.

- **L’Alliance pour l’Industrie du Futur** of Economy in July 2015, is a French association created by the ministry is a network of organisations set up in 2012 by the Technology Strategy which brings together industry & digital companies and research centres. It was first presented at the Smart Industry event held in Paris in September 2015. A first call for projects has been launched on technologies for the factory of the future.

- **Catapult Board of Innovate UK** (United Kingdom's innovation agency) to promote R&D toward high value manufacturing (HVM). In December 2014, the UK government decided to invest additional £89 million in the Catapult network.

Other up and coming national initiatives we deem interesting inside the EU are:

- **Smart Industry**: development of smart factories is the first point of the latest *Strategy Plan for a New Industrialisation in Sweden*, an investment plan backed by the Ministry of Enterprise and Innovation of the Swedish Government, aimed at boosting the digitalisation of all manufacturing processes in the country. Sweden has been a particularly fertile ground for innovation, having spent on average in the last ten years, 3.3% of GDP in R&D.

- **Industria Conectada 4.0**: new strategic initiative launched by the Ministry of Industry & Energy of the Spanish Government, whose goal is to follow through the process of digitalisation the whole Spanish manufacturing sector.

- **Piano Nazionale Industria 4.0**: investment plan backed by the Ministry of Economic Development of the Italian Government. The total funding will amount to €13 billion deferred in seven years (starting 2017) to sustain private investment, plus other €10 billion to maintain undergoing national initiatives for innovation. A particular interesting tool appears to be the “hyper-amortization” of 250% for investments regarding automatization, mechatronics, robotics, big data, nanotechnologies, new material and augmented reality.

A recent study commissioned by the European Parliament has pinpointed some €140 billion as total investment per year needed to sustain the entire process of smart-industrialisation of Europe:


2.1.2.3 **Beyond Europe**

The market analysis covers countries beyond Europe. SatisFactory will take advantage of international networks and organisations related to smart factories.

- The U.S. National Network for Manufacturing Innovation (NNMI) is a network of U.S. research institutes launched in 2012 with a proposed US$1 billion of public funding,
that focus on developing and commercializing manufacturing technologies through public-private partnerships.

- Smart Manufacturing Leadership Coalition (SMLC) is a U.S. non-profit organization committed to overcome barriers to the development and deployment of Smart Manufacturing (SM) System.
- Still in the USA, the Industrial Internet Consortium aims to accelerate the development of Industrial Internet technologies. The consortium (AT&T, Cisco, General Electric, IBM and Intel) founded the IIC in March 2014. The industrial Internet is based on various research areas such as cloud-based manufacturing, big data, cyber-physical system and machine-to-machine communication.

According to the Application Developers Alliance (ADA) companies from the Asia-Pacific area are expected to increase their manufacturing budgets from $9 billion in 2014 to $60 billion in 2020, a significant part of these R&I investments being dedicated to the Industrial Internet of Things.

As “the fourth industrial revolution” is expected to bind companies and countries even more tightly together through worldwide supply chains and sensor networks, it will increasingly promote globalization. At the same time, it will link closely to local companies. That helps explain why the aforementioned PwC survey results differed considerably by region. Asian companies, especially those based in Japan and China, expected the greatest gains from the digitization of Industry 4.0, followed by companies in the Americas, and then Europe and the Middle East. Japanese companies are already the most advanced in this field, followed by those based in the U.S. and then Europe. Companies in all regions expect to catch up within five years.
Respondents from three major regions were asked: “What cumulative benefits from digitization [in the context of an Industry 4.0-related survey] do you expect in the next five years?” Asia-Pacific had the largest percentage of companies with high expectations.

As Industry 4.0 takes hold around the world, emerging nations probably have the most to gain. They can leverage digitization to gain efficiency in their horizontal integration, working with the global manufacturers to whom they supply all manner of raw materials, parts, and components. This great integrating force is gaining strength at a time of political fragmentation — when many governments are considering making international trade more difficult. It may indeed become harder to move people and products across some national borders. Rumours regarding possible new tariffs on external goods proposed by American president elect, Donald J. Trump, Brexit and EU intestine battle against China market economy status clearly exemplify this situation. But Industry 4.0 could overcome those barriers by enabling companies to transfer just their intellectual property, including their software, while letting each nation maintain its own manufacturing networks.

Figure 6: Industry 4.0 expectations by region, exhibit 2

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6 Source: Industry 4.0: Building the Digital Enterprise, PwC
2.1.3 Technology trends

2.1.3.1 Key technologies for a fourth industrial revolution

Industry 4.0 (i.e. the fourth industrial revolution) is strongly related to the concept of Smart factories. Digital factories, Advanced manufacturing and the Industrial Internet of Things (IIoT). It means that everything in and around a manufacturing operation (suppliers, the plant, distributors, even the product itself) is digitally connected, providing a highly integrated value chain. Industry 4.0 is expected to enhance both productivity and working environment in factories. As is shown e.g. in the agenda of Hannover Messe 2016 (25 to 29 April 2016), Industry 4.0 is a trending topic.

Industry 4.0 depends on a number of new and innovative technological developments:

- The application of information and communication technology (ICT) to digitise information and integrate systems at all stages of product creation and use (including logistics and supply), both inside companies and across company boundaries;
- Cyber-physical systems and systems. These may involve embedded sensors, intelligent robots that can configure themselves to suit the immediate product to be created, or additive manufacturing (3D printing) devices; that use ICTs to monitor and control physical processes and systems. These may involve embed sensors, intelligent robots that can configure themselves to suit the immediate product to be created, or additive manufacturing (3D printing) devices;
- Network communications including wireless and internet technologies that serve to link machines, work products, systems and people, both within the manufacturing plant, and with suppliers and distributors;
- Simulation, establishment of manufacturing processes;
- Big data analysis: exploitation, either immediately on the factory floor, or through big data analysis and cloud computing;
- Greater ICT - based support for human workers, including robots, augmented reality and intelligent tools.

In particular, SatisFactory’s technologies will provide workers with real-time informational support via augmented reality glasses and other connected interfaces. These “body-adapted wearable electronics” has been identified by The World Economic Forum as one of the top 10 emerging technologies in 2014.

2.1.3.2 Investment in innovation in the manufacturing sector

According to the INNOBAROMETER 2015, 15% of manufacturing companies plan to use ICT-enabled intelligent manufacturing (i.e. technologies which digitalize the production processes) in the next 12 months.

Investment in innovation and new technologies

Since the onset of the economic crisis, dramatically reduced levels of investment in innovation are a major concern for Europe’s industrial future. The Commission has put an increasing share of its policy, regulatory and financial levers at the disposal of Member States, regions and industry to foster investment in innovation. The Horizon 2020 Programme, in particular through its industrial leadership pillar, will provide close to EUR 80 billion for research and innovation. This includes support for key enabling technologies that will redefine global value chains, enhance resource efficiency and reshape the international division of labour. [...] The need to speed up investment in breakthrough technologies in fast-growing areas was the main reason the Commission decided to identify in the 2012 Industrial
Policy Communication the six areas in which investment should be encouraged. These technologies, clean vehicles and transport, bio-based products, construction and raw materials and smart grids. The work of the six task forces that were set up a year ago, has enabled the Commission to identify opportunities as well as obstacles to innovation requiring further policy action.

(Source: EUROPEAN COMMISSION, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, For a European Industrial Renaissance, January 22, 2014).

2.1.3.3 Human-Centred Technologies; Workers’ well-being

Implementing positive psychology in the workplace means creating an environment that is relatively enjoyable and productive. The issue of happiness at work is increasingly frequent in world publications (cf. the two following graphs) and technology research (Human-Centred Technologies).

Figure 7: Frequency of the term “happiness at work” in Google Books between 1800 and 2008

Figure 8: Frequency of the term “happiness” and “work” in Google Books between 1800 and 2008

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7 Source: Google Ngram Viewer

8 Source: Google Ngram Viewer
2.2 DEFINITION OF EXPLOITABLE PRODUCTS AND CHARACTERISTICS

2.2.1 Single Technologies

This chapter contains a short description of exploitable products, resulting from the implementation of the SatisFactory project.

2.2.1.1 Middleware for Smart Factories

SatisFactory will leverage on an existing middleware solution developed in the EU Hydra project and being extended towards other EU projects. This solution will be tailored to a lightweight application that could run on cost-efficient hardware, such as Android based platforms or raspberry pi. The pursued goal is to implement a general purpose development platform that enables and makes easier the development of sustainable complex systems. Moreover, the SatisFactory project will extend LinkSmart by defining a low level adaptation interface that exposes in a common way the available application-domain resources. Thus, it will enable shop floor data aggregation, notification and control. It will facilitate and accelerate the development of heterogeneous device environments in a robust way, while offering improved usability and user experience.

2.2.1.2 Collaboration platform for manufacturing enterprises

SatisFactory will further develop the standard user-centred technology design methods in order to appropriately address the challenges of the shop floor environment. The methods then will be applied to elaborate in detail novel collaboration techniques supporting workers in interpersonal communication, problem solving, continuous learning and teamwork. SatisFactory will bridge the technical advances in UbiComp and the demand for attractive collaboration and interaction techniques at a factory site by involving situated embodied interaction through real-world (smart) objects and wearable devices in a way that respects such aspects of cooperation as awareness, transparency and privacy attitudes of workers. Moreover, SatisFactory will aim at lightweight and fun-to-use solutions offering improved collaboration possibilities and robustness.

SatisFactory will offer a novel gamified environment in order to enhance the attractiveness of the working environment, increase personal and organisational wellbeing and support the connection between workforce, management and technology. A framework supporting gamification will be developed and interfaces made available for managers to define new games, rules, and awards. This platform will support both anonymous and named participation. In particular, in the area of:

- The support of training
- Enhancement and stimulation of innovative problem solving through the use of social networking. To this aim, a suggestions platform will be developed and integrated with the gamification platform, allowing for both anonymous and named suggestions.
- Enhancement of employee engagement through the combination of game interaction elements and social networking.

Utilization of novel head mounted display in combination with augmented reality environment for an improved, easier and more attractive interconnection of personnel with technology.

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8 Source: Google Ngram Viewer
2.2.1.3  **Semantics and Context-aware knowledge shop floor analysis engine**

This engine aims towards deciding which information is relevant in certain situation(s) for certain user(s), taken into account the context of the information. This component is based on an approach tested within the FP7 LinkedDesign project to solve the problems of information assessment and comprehension by providing an ontology-based model and rules for its interpretation originating from “hands-on” knowledge and previous experience. It will be an engine that will be combined with other products to enhance their capabilities by offering a better understanding of the manufacturing processes and operations, the shop floor actors and machinery, the worker’s roles and responsibilities, the maintenance requirements and procedures and the daily production details and flaws. By utilising an open source semantic framework that can analyse real-time and historical information, every SatisFactory component can extract semantically enriched data for further improving operational results.

2.2.1.4  **Hardware HMI, HMD**

Exploitation of HMD potentiality as a device to be integrated into a complex framework such as an industrial plant can turn into a realistic option depending on how hardware issues such as miniaturization, form factor and usability features will be solved. Within SatisFactory, Glassup will further extend the features of their glasses, taking into account both ergonomics and other critical factors for end-users final acceptance in industrial applications. The use of smart glasses can serve for a two-ways data transfer. From the worker: He/she will be able to capture video and/or images and send them to a supervisor or to a remotely located technician, thus transmitting information on an issue at the moment he/she confronts it. To the worker: He/she will be able to receive information on the equipment and on the task in hand in an easy and quick way, without disturbing the course of the procedure, which could elevate the risk level for an accident.

A strategical strength point is the service support to the customers as integrator: the mix with product and services it’s a way for exploitation and customers loyalty building.

2.2.1.5  **Dynamic Re-adaptation of Production Facilities and HR workload balancing toolkit**

This product will allow for the re-adaptation of production facility by incorporating data for the status of the production processes, any flaws or malfunctions. The response could be an automated adjustment, the disruption of production, the call for human intervention or for application of corrective maintenance procedures. In the case that human intervention is required, it is important to allocate the right worker to do the right task based on their skills, availability and criticality of the task. The HR workload balancing toolkit is going to do just that, offering the ability to manage effectively the human resources available on the shop floor level at all times. The objectives of the toolkit are to assign new tasks to the most appropriate human resources based on the current status and experience gained from past task allocations, to automatically re-adapt their worklist if needed, and to keep the workload balanced among the workers. This tool will be very useful for environments where high specification in skills is required to perform certain tasks or when production or commissioning issues required for fast and efficient re-adaptation of the human resources. The toolkit will take into consideration the specific workload of individual workers along with other parameters and task characteristics, leveraging the weight of overtime required due to inefficient scheduling and balancing.
2.2.1.6 **Feedback Engine (Incident management)**

The Feedback Engine represents a substantial role in the everyday activities of actors involved supporting workers’ safety and comfort. The main goal of the module is the detection of proactive and reactive incidents on the shop floor with the use of depth and thermal sensors. The system monitors the activities on the shop floor, detects and alerts the possibility of a risky condition (proactive incident) and incidents after their occurrence (reactive) based on real-time data. In both cases, the tool performs the corresponding predefined countermeasures. Health and Safety issues are very important and critical and the avoidance of incidents and/or the effective response to incident is very crucial for all manufacturing companies and their workers. The use of this tool will help the workers feel that they work in a safe environment, thus offering considerable benefits. Moreover, the use of only privacy preserving sensors will assure the respect of the personnel’s legal and ethical rights.

In particular, the depth camera incident detection system aims at the immediate recognition and notification of incidents such as human falls, falling items, collisions between moving objects and intrusions to restricted areas. Once an incident is detected an alarm notifying of the type and location of the event is set so that the appropriate coping mechanism can be immediately triggered providing an important leverage to the domain of occupational health and safety. In addition, the thermal camera incident detection system provides mechanisms for early defect diagnosis of major faults, associated with a sudden increase in the equipment's temperature profile. Following condition monitoring techniques, the system can alert that a risky condition occurred on the shop floor, thus, minimize repair costs, reduce unscheduled down time and prevent catastrophic failures. All the above have a direct impact on employee satisfaction, since they lead to safer working environments.

2.2.1.7 **On-the-job training toolkit**

On-the-job training is going to be accomplished using the AR platform developed by REGOLA for industrial environments with support from plugins by CERTH providing state-of-the-art augmented reality technologies such as markerless object recognition, registration and tracking. ABE contributes with the ICT tools and models for the evaluation of the training, in order to optimise the effect of the use of the toolkit. The improved toolkit will integrate AR technologies and wearable as well as portable features. It will be further developed taking into account the end user requirements (D1.1) and the use cases to be implemented in the industrial lab use case and the end-user industrial pilots (D1.2). The application of the toolkit will focus on manufacturing, assembling and maintenance training scenarios.

2.2.1.8 **Real-time localization of workers, tools and machines**

The real-time localization is enabled by UWB-based wearable devices developed by ISMB. These devices have a unique identifier that allows distinguishing different workers / objects to be localized at the shop floor. UWB-based wearable devices provide as output location information on the basis on both collected ranging measurements from fixed UWB devices, deployed at the shop floor, and inertial measurements from on-board sensors. Localization data generated by the wearables devices are processed by a software module called “Localization Manager” that implements a geo fencing logics in order to detect when a worker approaches or is inside a dangerous/forbidden area.
2.2.1.9 **Smart Sensor Network for Industrial Applications**

SatisFactory will provide a significant progress in the definition of cognitive multi-radio management mechanisms enabling near-real-time knowledge and inference of network status while allowing adaptive and prompt reaction to potential communication interruptions. Given this intelligence, the Smart Sensor Network (SSN) component provides communication robustness in harsh industrial environments by leveraging heterogeneous wireless technologies, such as Wi-Fi and IEEE 802.15.4. The development of the SSN component is led by ISMB given its expertise in networked embedded systems. It will be possible to adjust and integrate to existing infrastructures or to migrate the existing sensors to the SatisFactory SSN.

2.2.1.10 **Integrated shop floor DSS**

The DSS will collect evidence from real-time data coming from the shop floor through the plug-and-share smart sensor network and from detected incidents, coupled with prescribed response strategies. SatisFactory will provide a novel and unique DSS system, which goes well beyond the current state-of-the-art, addressing the needs for:

- semantic modelling of manufacturing knowledge spaces and processes, of shop floor actors and machinery
- collection of evidence from real-time data coming from the shop floor through the "plug-and-share" multi-sensorial monitoring framework
- collection of evidence in the form of detected incidents, coupled with prescribed response strategies in order to offer feedback to the shop floor in terms of actionable knowledge and recommendations, including maintenance operations and schedules.

2.2.2 **Bundles of Products**

**The Customer Point of View**

The SatisFactory project outcomes are described in the previous sections as separate technologies, according with the lines of the project development. However, the interaction with key stakeholders and potential customers shown that the best solution which addresses a specific need, often requires a combination of multiple SatisFactory technologies. We call the combination of single technologies: "Bundle".

The exploitation of SatisFactory results requires to assume, as much as possible, the point of view of the potential users. Sometime, a use of a different language is required, since the language of people involved in the use of technical developments is often quite different from the one of the developers.

The collaboration with key stakeholders and potential clients also revealed that the communication becomes more effective when it is focused on the solution proposed regarding a real problem and a perceived need of process improvement. As far as selling the SatisFactory tools is concerned, products have to be presented in a way that one can figure out the technology applied in its context. In this way, customers can have a better understanding of the tool and appreciate its full potential.
The SatisFactory project is a collaborative one and so are their products, which can be offered in total as a complete solution or combined in bundles or even as individual products. The synergies and the possibilities will be examined as the project progresses.

Examples of combination in product suites are:

- Smart Sensor Network and Middleware
- Localisation Manager and On-the-job training
- HR workload balancing and Integrated DSS and HMIs
- HR workload balancing and Social network and collaboration platform, etc.

In any case of cooperative work leading to joint ownership issues, a Business Agreement should be signed (cf. section 4.4).

The following paragraphs contain the description of the Bundles introduced so far. The rational of this choice is that we have considered as first, the technologies with a higher TRL to date, also corresponding to possible use cases that have been identified.

### 2.2.2.1 IamDSS

Bundle IamDSS is the result of the collaborative work of ABE, CERTH/CPERI, CERTH/ITI, REGOLA and ISMB, with the option of FIT involvement. The **IamDSS** (Intelligent Asset Management Decision Support System) receives input on events taking place at shop floor level, capitalising on the alternative Incident Detection modules. The combination of real-time and historical data enables the assessment of the status of the shop floor. IamDSS uses machine learning algorithms to gradually phase out false alarms. It can be integrated with existing sensorial network and can be coupled with middleware solutions; it is already integrated with LinkSmart. The innovation is the provision of a complete system, which allows to:

- Semantically model manufacturing knowledge spaces and processes, shop floor actors and machinery.
- Collect evidence from real-time data from the shop floor through the “plug-and-share” multi-sensorial monitoring framework and combine it with historical data.
- Connect the detected incidents with response strategies using a Rule Engine, in order to offer feedback to the shop floor in terms of actionable knowledge and recommendations, including maintenance operations and schedules.
- Perform human resources workload balance analysis, taking into consideration pending tasks and intercalary ones, as well as preventive maintenance schedule, together with employee availability and skills.
• Provide actionable knowledge in the form of Standard Operating Procedures with the information/data necessary to complete the necessary task(s) to the involved personnel in attractive ways, using either a mobile application or an Augmented Reality Operational Platform.

• Offer the supervisor with a complete and detailed view of the shop floor (machine and personnel status, notifications, alarms, incident) in one user friendly screen, which in turn allows connection to more details for a specific entry, if desired.

The components forming the IamDSS bundle are the following.

Table 1: IamDSS Components

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>iDSS</td>
<td>Necessary</td>
</tr>
<tr>
<td>Incident Detection modules</td>
<td>Necessary</td>
</tr>
<tr>
<td>(at least one from labeled Option (i) in the Incident Detection bundle)</td>
<td></td>
</tr>
<tr>
<td>HR workload balancing</td>
<td>Optional</td>
</tr>
<tr>
<td>AR Operational Platform</td>
<td>Optional</td>
</tr>
<tr>
<td>Re-adaptation of production facilities</td>
<td>Optional</td>
</tr>
</tbody>
</table>

The Incident Detection bundle is comprised of the following components.

Table 2: Incident Detection Components

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrated Visualization or Re-adaptation toolkit</td>
<td>Necessary</td>
</tr>
<tr>
<td>Thermal Cameras</td>
<td>Option (i)</td>
</tr>
<tr>
<td>Depth Cameras</td>
<td>Option (i)</td>
</tr>
<tr>
<td>UWB-based Localization Manager</td>
<td>Option (i)</td>
</tr>
</tbody>
</table>
2.2.2.2 **STuDIOUS - Smart IncidenT Detection System for OccUpational Safety**

Bundle STuDIOUS Id4OS is the result of the collaborative work of ISMB, CERTH, GLASSUP and FIT with the option of EPFL and ABE involvement. The STuDIOUS (Smart incidenT Detection System for OccUpational Safety) aims to support workers’ safety during their daily operations by leveraging location information, media and gesture recognition data as well as environmental parameters. This allows achieving a safer and more productive working environment. In particular, the system continuously monitors the activities on the shop floor and detects in real-time possible risky conditions as well as accidents that might occur or have occurred in the shop floor. In addition, it performs the corresponding predefined countermeasures. In particular, the system will be able to detect incident events such as: a worker is perceived to be inside a dangerous/forbidden area, a worker does not wear the necessary safety equipment, a worker has fallen or a collision has occurred. Besides perceiving events related to workers, falling objects and overheated units are detected as well as abnormal environmental conditions.

STuDIOUS offers a variety of complementary solutions that allow the detection of different incident events leveraging multiple technologies. In this way, according to a specific set of requirements and technology constrains, each costumer will be able to choose the best solution ensuring the maximum safety of the workers in its shop floor.

**Involved products:** Middleware for smart factories, semantics and context-aware knowledge shop floor analysis engine, hardware HMI / HMD, feedback engine, real-time localization of workers, tools and machines, smart sensor network for industrial applications and integrated shop floor DSS.

**Involved Components:** Smart Sensor Network (IoT sensors with robust communication, UWB localization devices, depth/thermal cameras, legacy sensors), Middleware, Context-Aware Manager (Localization Manager, Multiple-media Manager, Gesture & Content Recognition Manager, Depth & Thermal Cameras Manager), Ontology Manager, Integrated DSS, hardware HMI / HMD, CIDEM.

**Related Deliverables:** D3.3, D4.1.

The involved products forming the STuDIOUS bundle are the following.

<table>
<thead>
<tr>
<th>Product</th>
<th>Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gestures and Content Recognition Manager</td>
<td>Option (i)</td>
</tr>
<tr>
<td>AR Glasses</td>
<td>Option (i)</td>
</tr>
<tr>
<td>Plant Data Exchange Component</td>
<td>Option (i)</td>
</tr>
<tr>
<td>Multimedia Manager</td>
<td>Optional</td>
</tr>
</tbody>
</table>
Table 3: Involved products

<table>
<thead>
<tr>
<th>Product</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedback engine</td>
<td>Necessary</td>
</tr>
<tr>
<td>Middleware for smart factories</td>
<td>Necessary</td>
</tr>
<tr>
<td>Hardware HMI / HMD</td>
<td>Necessary</td>
</tr>
<tr>
<td>Real-time localization of workers tools and machines</td>
<td>Necessary</td>
</tr>
<tr>
<td>Semantics and context-aware knowledge shop floor analysis engine</td>
<td>Optional</td>
</tr>
<tr>
<td>Integrated shop floor DSS</td>
<td>Optional</td>
</tr>
<tr>
<td>Smart sensor network for industrial applications</td>
<td>Optional</td>
</tr>
</tbody>
</table>

The involved SatisFactory components comprised in the products presented previously are the following.

Table 4: Involved SatisFactory components

<table>
<thead>
<tr>
<th>SatisFactory Component</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>UWB localization devices</td>
<td>Necessary</td>
</tr>
<tr>
<td>Depth / thermal sensor network</td>
<td>Necessary</td>
</tr>
<tr>
<td>Middleware</td>
<td>Necessary</td>
</tr>
<tr>
<td>Localization manager</td>
<td>Necessary</td>
</tr>
<tr>
<td>Multiple-media manager</td>
<td>Necessary</td>
</tr>
<tr>
<td>Gesture &amp; content recognition manager</td>
<td>Necessary</td>
</tr>
<tr>
<td>Hardware HMI / HMD</td>
<td>Necessary</td>
</tr>
<tr>
<td>Ontology manager</td>
<td>Optional</td>
</tr>
<tr>
<td>Integrated DSS</td>
<td>Optional</td>
</tr>
<tr>
<td>IoT sensors with robust communication</td>
<td>Optional -they can be added according to the environmental data to monitor</td>
</tr>
<tr>
<td>Legacy sensors</td>
<td>Optional</td>
</tr>
<tr>
<td>CIDEM</td>
<td>Optional</td>
</tr>
</tbody>
</table>
2.2.2.3 FRACTAR – FRAmework of Creative Tools for Augmented Reality

Bundle FRACTAR is the result of the collaborative work of CERTH/ITI, REGOLA, GlassUP and ISMB, with the option of FIT involvement.

Help workers during the manufacturing in the shop floor. It is integrated with the Intelligent IoT Platform. The AR platform merges its Augmented Reality and Virtual Reality capability in the context of the Standard Operating Procedures. Its software architecture is based on the following tools:

- The Creation Tool, a Windows based application which is able to create, edit and deploy Standard Operating Procedures. It is a software tool featuring an highly expressive power, i.e. able to implement complex procedures, including rich content, and to deploy them on the target platform.
- The Presentation Tool, a multiplatform application able to execute and serve Standard Operating Procedures over a range of platforms having different capabilities, as Tablet, Smartphones, personal computers, wearable
- Object recognition tools. These are software and hardware platforms carrying out specific tasks improving the capability of the Presentation Tool. A typical example is the Object Recognition Server, i.e. a powerful workstation able to recognize object in a scene to validate assembling procedure steps.

The AR platform fully redefines the definition of Standard Procedure: the procedure has no more fuzzy boundaries, it is no more composed by a bunch of different files with different formats, independently managed, but is now a single document, stand-alone rich media digital bundle that could be easily downloaded where it is needed in its up-to-date version. The procedure efficiently implemented by the Creation Tool, able to share common resources in different procedures, produces a bundle that, when interpreted and executed by the presentation tool, makes the operator able to perform conditional procedures, based on the instant value of sensor readings, thus fully exploiting the IoT infrastructure available, that could easily take advantage of its AR/VR engine. This way, assembly, training and maintenance procedures could take advantage of the state of the art Augmented Reality engine to show to the operator proper content providing all the information required to efficiently complete the current tasks. The AR engine allows for marker recognition, markerless recognition and recognition by means of fiducial markers. In its job, the Presentation Tool could take advantage of other platforms, like the Object Recognition Server, a powerful workstation able to detect manufacts in the scene, communicating to the Presentation Tool if the requested object are found and their position. The whole platform has a plugin based architecture that make it flexible in arranging new functions when required. An example of such added capability is the View Channeling communication layer, enabling the Presentation Tool to receive prioritized, rich media dispatches, to all the component in the network implementing its protocol. This way the Procedures are served over a platform being natively designed to be integrated company wide.
The *Fractar* bundle is comprised of the following components:

**Table 5: Fractar components**

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMD-GlassUP</td>
<td>Optional</td>
</tr>
<tr>
<td>UWB Localisation tool</td>
<td>Optional</td>
</tr>
<tr>
<td>Collaboration Platform</td>
<td>Optional</td>
</tr>
<tr>
<td>Markerless recognition Engine</td>
<td>Optional</td>
</tr>
<tr>
<td>Smart Sensor Network for Industrial Applications</td>
<td>Optional</td>
</tr>
</tbody>
</table>
2.2.2.4 **DISC-IT**

Bundle DISC-IT is an extension of the On-The-Job and Lab Training platform and result of the collaborative work of REGOLA, CERTH/ITI, ABE, GLASSUP and ISMB.

That includes:

- The Regola R3D platform plus
- Communication tool
- Metrics for Performance benchmark and for Tutor based and Self-evaluation training approach

Support for:

- Mobile (Android, IOS and Microsoft Mobile)
- Smart Glasses

The Training Platform is composed by a set of tool:

- The Training Creation Tool (TCT)
- The Training Presentation Tool (TPT)
- The Training Data Analytics Tool (TDAT) and its visual interface
- The Ontology Manager (OM)

By means of those tools it is possible to carry out and improve a training process using, as building blocks, the training sessions and the training procedures. Training sessions are named containers for a set of training operating procedures. The procedures could then be played by the TPT, that is able to provide surveys to the trainee and a set of audit data feeding the TDAT. The TDAT is able to extract, from that audit data, KPIs which could be used to assess the skills of the trainee and the quality of the training procedures and sessions. Those KPIs could be further processed by the OM in order to compute new, more meaningful KPIs enabling better understanding about the trainee and the overall training provided. This means that the professional at the keyboard of the training creation tool could improve the training provided to the trainees by means of the platform deployed acting on two independent factors: first, at container level, including or excluding training procedures; second, at training procedure level, editing the single procedures. In other words, the TDAT transforms training audit data in KPIs; OM transform KPIs in KPIs according with specific rules. These transformations are intended to: A) refine the classification of the trainee B) provide insight that could be used to edit TS and TP in order to improve them. This feedback allows for a continuous quality improvement of the Training sessions / procedures and enables several possibilities:

- Within a production environment, a job description could provided as a set of TS required to complete a job, where each TP has a minimum threshold score.
- The worker's profile could be defined by the set of the TP / TS completed by that worker.
- The fitness of a worker for a given job could be expressed as a statement about the fact that the candidate has performed the required set of TSI achieving, at least, the minimum acceptable score required for each of them by the job profile.

The **DISC-IT** bundle is comprised of the following components:
### Table 6 Disc-IT platform components

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMD-GlassUP</td>
<td>Optional</td>
</tr>
<tr>
<td>UWB Localisation tool</td>
<td>Optional</td>
</tr>
<tr>
<td>Collaboration Platform</td>
<td>Optional</td>
</tr>
<tr>
<td>Markerless recognition Engine</td>
<td>Optional</td>
</tr>
<tr>
<td>Smart Sensor Network for Industrial Applications</td>
<td>Optional</td>
</tr>
</tbody>
</table>
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[4] DEUTSCHE BANK, Europe’s re-industrialisation The gulf between aspiration and reality, November 26, 2013


[6] EUROPEAN COMMISSION, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, For a European Industrial Renaissance, January 22, 2014


