Micro-Factory 4.0: Sugar Production Micro-Plant

Authors:

Daniel Wilbert Hendrason
Dwi Cahyo Wibowo
Hamyrez Jorghi Oszarwin
Marcell Raffaello Hartanto
Sonya Indriastuti

Facilitators & Editors:

Dr. Ir. Prianggada Indra Tanaya, MME
Dr. Samuel PD Anantadjaya, MBA, MM
Irma M Nawangwulan, MBA, CPM (Asia)

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Author(s)	:	Daniel Wilbert Hendrason, Dwi Cahyo Wibowo, Hamyrez Jorghi Oszarwin, Marcell Raffaello Hartanto & Sonya Indriastuti
Facilitators & Editor(s)	:	Dr. Prianggada Indra Tanaya & Dr. Samuel PD Anantadjaya
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Preface

We are thankful to Dr. Paul Gromball for providing us with guidance and lecture about the industry 4.0 and the opportunity to write a report containing our ideas and projection of industry 4.0 micro-factory for sugar.

We would also like to thank our classmates during the industry 4.0 class for their feedback and exchange of knowledge, in helping us to be creating this report.

We would like to thank our anonymous referees for their useful insights and suggestions. Also, we would like to thank Dr. Tutuko Prajogo, Dr. Prianggada Indra Tanaya. and Ir. Invanos Tertiana, MBA for their time to enlighten us so that this report becomes more than what we expected. Also, we would like to thank Dr. Samuel PD Anantadjaya for his support in editing this report.

We certainly hope that this report is able to provide a quick glimpse on the tip of the iceberg on the potential disruptions of the micro-factory 4.0

BSD City, Serpong, Tangerang

December 2019,

Daniel, Dwi, Marcel, Hamyrez & Sonya

Introduction

Technologie Management Gruppe, also known as TMG-Muenchen, collaborated with IULI to make a 5 lecture about the Micro-Factory 4.0 with the students of the Automation course. This course aims to bring the student closer into automation and IoT by having the knowledge of Micro-Factory 4.0 and what is needed to realize such things. The course is brought by using the AlfaView program where all the attendants could log on to the classroom from everywhere. This is a great idea since some of the students, especially the lecturers do not have to be in the same physical classroom. The lecturer of this program was brought by Dr. Paul Gromball and his associates from TMG Mr. Norbern Kehl. Not only students but lecturers from IULI also took part in this program as the enthusiasm for learning the course and help the students get a better understanding of the programs.

Not just a simple lecture, the course gave us an opportunity to try to implement a common factory into a smart micro-factory by using all the tools given. Our group decided to build a sugar production micro-factory that is going to give back to the community. According to McDonald & Meylinah (2019) report on an Indonesian sugar plantation, over 1,328,250 families are involved, and of course, Local sugar mills are aging, with approximately 40 mills over 100 years old. Only six sugar mills are less than 25 years old. The older machinery results in poor recovery rates and is a disincentive to farmers, who are paid based on the recovery rate. State-owned sugar mills set a minimum recovery rate as a reference to pay farmers. Whenever farmers' actual recovery rate falls below the minimum reference, sugar mills will continue paying farmers at the minimum reference level. As a result, there is a disincentive for farmers to frequently re-plant to try to boost productivity. Farmers also obtain higher margins from growing paddy or corn, providing further disincentive to plant sugarcane. Land conversion for infrastructure development and other non-agriculture uses continues to reduce land availability for sugar and other crops. The idea is to optimize the process of sugar production by having an Internet of Things inside the plant. In this report, we are going to write about our understanding of the course and the project that we try to implement the Micro-Factory 4.0 knowledge. This will mostly be referenced straight from Dr. Gromball's lectures and other sources that we have searched through the internet to get a better understanding of the project.

Report Activity

MICRO FACTORY

The micro-factory is a small compact factory that produces small dimension products using small manufacturing facilities. In terms of micro-factory, the advantages are the capability to save a great number of resources such as space, energy, materials and time (Briggs, 2017). However, in order to conduct a micro-factory, the aspect of automation must be applied. Automation is a necessary part of the micro-factory due to the limited size of the factory itself. This is due to automation that could suffice the production demand needed, without the factory having lots of workers inside. So, in a sense, it is a method to replace unnecessary workers by utilizing the help of the latest technology. Furthermore, this method could solve other problems related to small factories such as the security factor, land cost, and productivity. In terms of security factors, micro-factory could serve as a solution due to the compact size of the factory itself. Since, compared to the amount of time for checking the process and materials conducted in a “big” size factory, a micro-factory could conduct a check much more frequent and faster. This will later lead to the elimination of the chances for the workers to steal the raw material and final product of the factory. In terms of land cost, since the micro-factory only needs a minimum amount of land, then it would ease the cost of buying or renting the needed rent. In terms of productivity, since the manufacturing process would be integrated with automation, then the whole process would rally from the beginning to the end process. This would make the process in terms of time much more efficient and effective since it could increase the number of products that could be created, and the flow of production is constant. The common automation applied in micro-factories are; automatic machine tools, assembly systems, quality inspection systems, waste elimination systems, etc. (Slepov, 2016)

INTERNET OF THINGS (IOT)

Internet of things is the concept of connecting any kind of device to the Internet, which helps humanity on a daily basis (Morgan, 2014). The Internet of things helps humans mostly in productivity since it could transfer data over a network without a human-to-human interaction. This helps the company in keeping its important data from a competitor and allows most of humanity to be connected to the whole world through interaction anywhere and anytime without additional delays needed. Other than productivity, the internet of things could also be implemented in other segments of the industry such as the health industry's heart monitor implant, farm industry's biochip transponder, automobile's sensors, etc. (Rouse, n.d.) However, in order to implement the internet of things, the merit and demerit of this method itself is the necessity of the access of the devices itself to the internet. So, in a sense, if the needed devices are connected to the internet then this method is ready to use. However, the additional demerit is the stability of the internet itself. So, even if there is internet in the area of implementation, however, if the connection is not stable then it would remain as a problem since the function is not operating as it should have. The common example of the internet of things is multifunction of a smartphone, with the connection of the internet a single smartphone could now help its users to read books, hear songs, chat their friends, and use many other applications.

ADDITIVE MANUFACTURING

Additive manufacturing is a technology advancement that brings flexibility and efficiency to manufacturing operations. Additive manufacturing utilizes data computer-aided-design (CAD) software to create objects in a manufacturing process, it applies technologies that grow three-dimensional objects one superfine layer at a time. Each successive layer bonds to the preceding layer of melted or partially melted material. Additive manufacturing technologies are commonly viewed in three types, which are; sintering, melting, and stereolithography (General Electric, n.d.). Sintering is the concept of heating a material and create a high-resolution object from it. Melting is the concept like *sintering*, however, the whole material is deforming first before it will be formed into a different object. Stereolithography is a method that utilizes a process called photopolymerization, whereby an ultraviolet laser is fired into a vat of photopolymer resin to create torque-resistant ceramic parts able to endure extreme temperatures (TWI, n.d.). The common discussion used in additive manufacturing is “3D printing” and “rapid prototyping” since it performs Rapid prototyping, complex part manufacturing, and spare part creation.

INDUSTRY 4.0 SOLUTION

As we know, the fourth industrial revolution brings so many possibilities and of course, the implementation of it is complicated. In the Micro-Factory 4.0 lectures, there are solutions for industry 4.0 which are like the figure below:

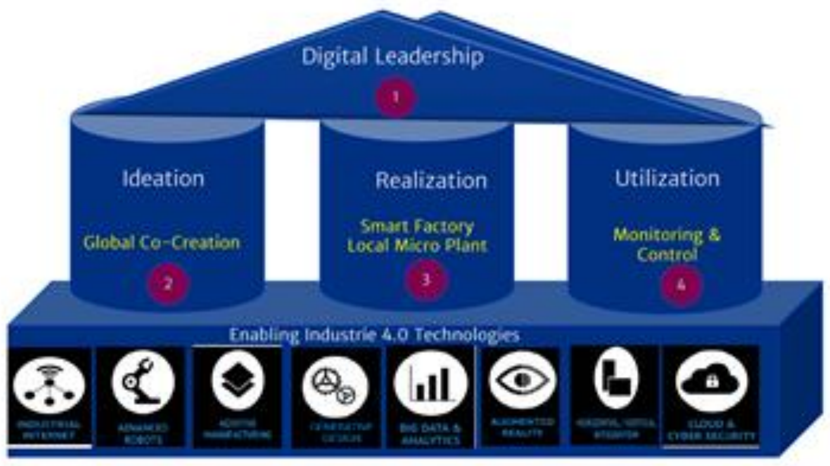

Figure 1: Industry 4.0 Solution
Source: (Gromball, 2019)

Digital Leadership

According to Briggs (2017), leaders, if they want to successfully pass the digital phase, have pushed their organizations to move forward into the digital age. Digital is an energy force that must be resolved and maximized by leaders if not, the backwardness of organizations that have been digitally increased. Digital leadership is an important point in the present because almost all industrial and business sectors have used digital principles. The acceleration of digital adoption and its impact is expected to double every year. A digital leader will:

- Use data-driven analysis rather than subjective analysis
- Set vision rather than aspiration
- Develop customer or citizen-based strategy rather than inside-out plans
- Outline coherent action rather than disjointed performance programs
- Focus on outcomes rather than outputs

Overall, digital leadership means to guide others and the community to realize the new industrial revolution. Because if people are not aware and do not know what or how to use it, it will not be effective at all and implementing smart technologies to the factory will not work. Therefore, we must have a digital leadership to guide others towards the new industry and through what is going to be next.

Ideation

Ideation is the process where you generate ideas and solutions through sessions such as sketching, prototyping, brainstorming, brainwriting, worst possible idea, and a wealth of other ideation techniques. In the industry 4.0 resolution, we use a variety of new types for our use in micro-factories which require some new to start in this business sector. In this section, creativity is needed to build a system that is new, fresh, and easy to live. Because the new system will be applied to computerization, basically this system requires simple things to easily do. By having the global co-creation, we generate ideas on what can be implemented and what would be the results of that implementation. In this case, we are going to create a sugar production micro-factory. The idea is to implement IoT to increase productivity and reduce the area required so that it could be placed in the cane plantation so that the sugar cane can be processed right after harvesting. It will not only improve our business process, but it will create a social responsibility where we could give back to the farmer's community. We will be the digital leader, teach them how to use the technologies and guide them through a better future.

Realization

Realization in terms of Industry 4.0 solution is the method in implementing the concept created in the ideation step or in other words, would be bringing the concept to the real world. Since the concept from ideation will be revolving in applying the automation of a smart factory or local micro plant. Realization is the step in applying the roadmap of the manufacturing process in the smart factory or local micro plant. The common aspects needed in realization is determining the number of labors, area or space needed, operation process chart, and the ideation itself. Through the ideation, industry 4.0 could be applied since the needed automation could be determined after the whole concept is created. Realization could be answered by applying the manufacturing operation module (MOM) or by applying the internet of things to the manufacturing process. This is due to both processes serve as a common concept for industry 4.0 solution. The simple example of realization is by creating a micro-factory from a sugar plantation that applies the labor of the workers from the sugar cane plantation itself to the creation of sugar from the sugar cane surrounding the micro-factory simultaneously.

Utilization

Utilization is based on the use of improvised equipment but produces maximum products. In this case industry, 4.0 utilization is divided into 2 sectors, namely in terms of equipment and in terms of raw materials. For the aspect of equipment, utilization can be interpreted as the use of tools to the limit of its ability to produce a product. So, the product produced is the best result. From the raw material sector, utilization for use in terms of raw materials becomes finished material. All uses of these materials can be used as much as possible. Not only the finished goods we produce but the waste generated can be reused. Utilization also tells us about how to utilize such technologies so that it will be effective and efficient in the process. Moreover, utilization is about control and monitoring. Later, in this sugar case, we can see how we can wee control and monitor the production using a different implementation of automation and cloud-based monitoring.

UNDERSTANDING AUTOMATION

Automation helps us to selective in reducing the manual operations that not requires, also to help operations that are repetitive and continuous. The sugar automation process will produce more, same quality and using the factory with higher efficiency by optimizing the energy use and environmental impact. There are several types of automation that SCADA is (supervisory control and data acquisition) that control industry systems based on the computer such as industry proses, infrastructure proses, and facility processes. This involves an automation network for a long-range but strong and steady but does not need high speed and computing power. The second one is PLC (programmable logic controller): deployed for factory automation applications with high-speed requirements and many discrete incoming and outgoing (I/O) communication channels. Distributed control system (DCS): used in process automation applications requiring high computing power. There are two variants of DCS, essential automation and extended automation. Essential automation is scalable and easy to use, providing automation for small- and medium-sized operations. Extended automation is for customers who want to go beyond the classical scope of a DCS, involving a rich context of information whereby telecommunications, video and/or the power supply side of a plant are integrated along with automating the process. Also, Automation is based on 3 classes of field equipment which are measurement products which using our sense of ear and eyes of the operation, actuation products like motors and drives are the power that gets something done in the field, control systems which the brain and nervous system of the plant. To develop an automated interface, ANSI/ISA-95 or ISA-95 standard was introduced and implement to all industries which the process like batch, continuous and repetitive. The purpose to give consistent terminology that is a base for supplier and manufacturer communications. (ABB, 2018)

LEVELS OF AUTOMATION

Level 0 – Field level – defines actual physical processes and contains the field devices such as flow and temperature sensors and final control elements such as control valves.

Level 1 – Direct control – defines activities involved in sensing and manipulating the physical processes and is the traditional instrumentation level with PLC systems and controllers as well as complete process controllers. It contains the Input/ Output (I/O) modules and their associated distributed electronic pro-censors.

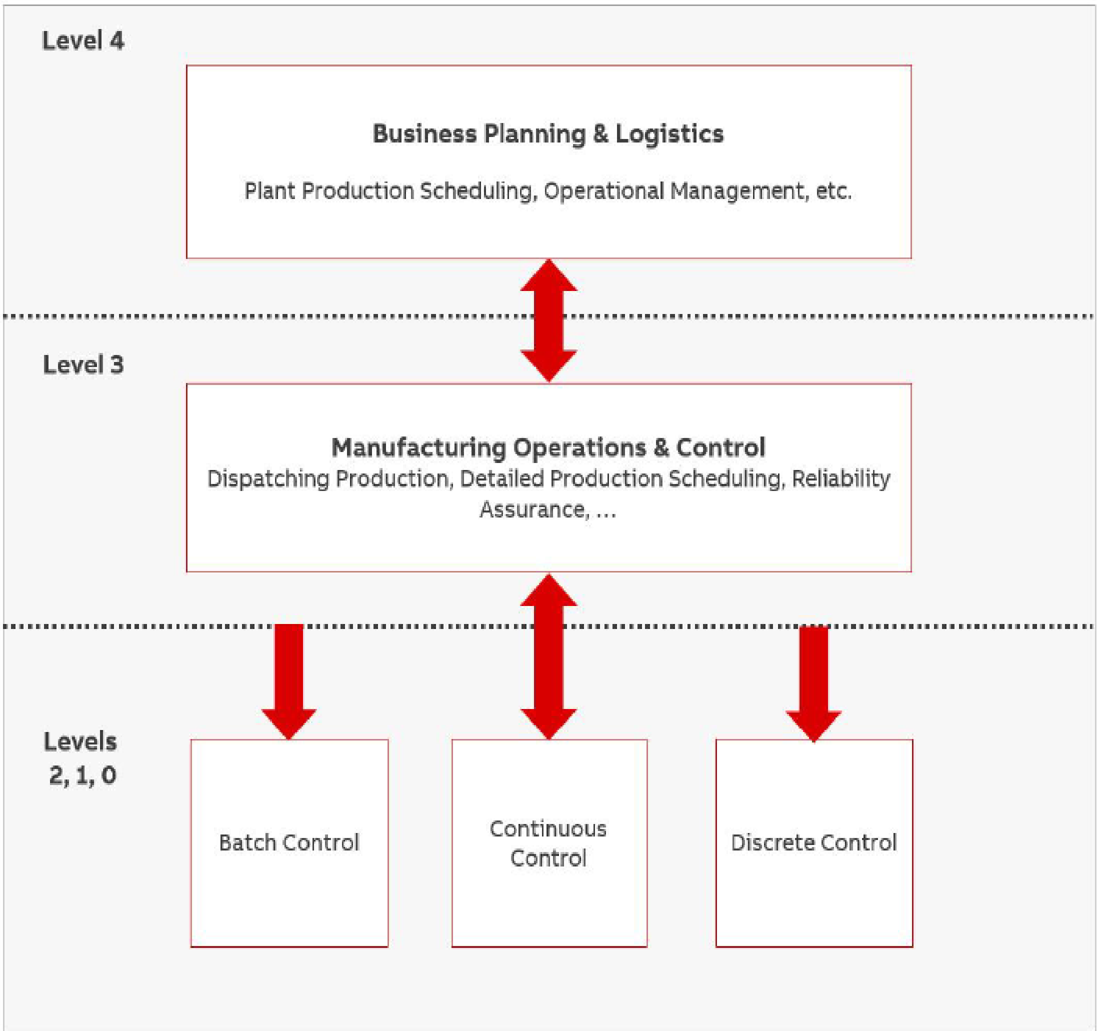

Figure 2: ISA-95 model
Source: (ABB, 2018)

Level 2 – Plant supervisory – defines activities of monitoring and controlling the physical processes. It comprises plant control of sub-processes for optimization of yields, often using advanced sensors or automatic analyzers directly in the process. PLC, SCADA, and DCS operate here, collecting all process data from Level 1.

Level 3 – Production control – defines activities of the workflow to produce the desired end products. It does not directly control the process but monitors production and targets. It includes systems for pro-duction coordination across whole plants to minimize costs and maximize yields and quality control. Typically, these are managed via manufacturing execution systems (MES), which analyze and control various elements of the production process (e.g., staff, inputs, equipment) in real-time. This helps decision-makers understand how existing conditions in each plant can be optimized to improve output. This is where the Manufacturing Operations Management (MOM) solution comes into play. MOM is a comprehensive, scalable and modular suite that encompasses process intelligence, manufacturing execution, production intelligence, and production optimization. Using data from Level 2 MOM undertakes historical trend analysis and key performance indicators.

Level 4 – Production scheduling – defines business-related activities needed to manage a manufacturing organization. It covers Enterprise Resource Planning (ERP) systems and takes this to the next level by allowing companies to manage similar variables across multiple, geographically dispersed production sites while also automating many back-office functions. ERP passes data back to Level 3 for it to be then translated into action at Level 2.

PROJECT RESULT

Project-Based

In our digital leadership sugar factory, we find the problem, "Disconnects of operational control in Indonesian Sugar Plant sugar." From these problems, according to our analysis, the sugar factory uses the industry 4.0 system, all of which use semi-automatic systems. The purpose of this semi-automatic is still needed human power to control the system that has been made. In addition to using human labor in the control room, we use human labor to collect sugarcane farmers' crops. Because our goal is to advance the commodity of sugarcane farmers around which is expected to advance the economy around the sugar factory. In addition to promoting the surrounding economy, we also aim to produce sugar that is better in terms of quality and saves time in producing it.

The idea generation or the reason we choose to implement the sugar production is that sugar is one of the commodities in Indonesia. Sugar production in Indonesia uses cane sugar because it is a tropical area. In the sugar making process, there are 6 overall steps in creating the sugar. There are planting and harvesting canes, preparation, and processing, juice extraction, crystallization, centrifugation, drying, and packaging.

The following illustration shows the operation process chart of sugar

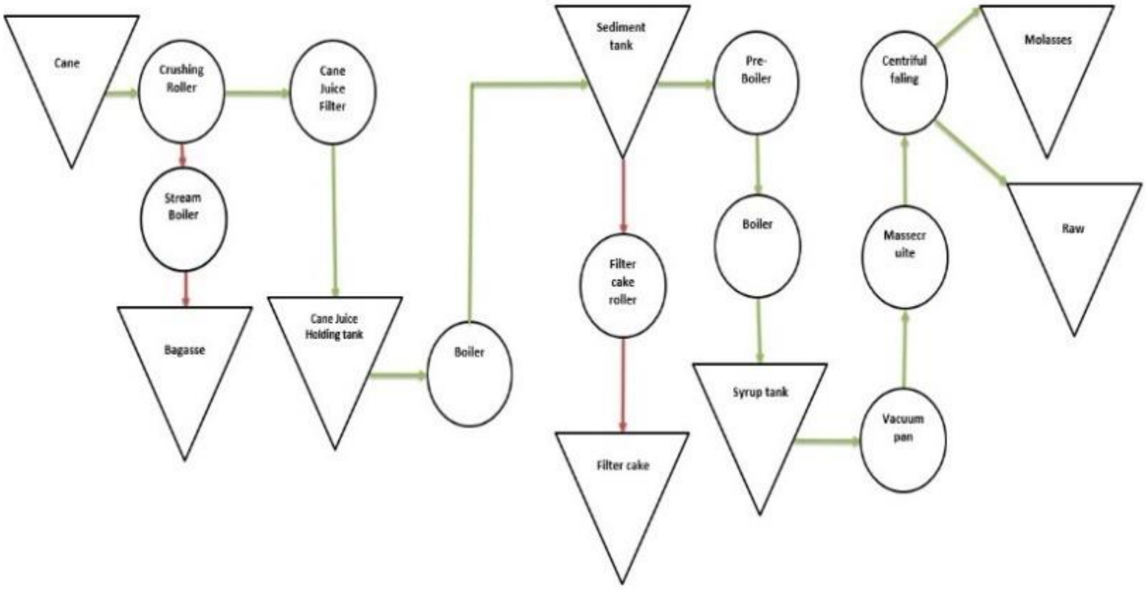

Figure 3: Operation Process Chart of Sugar
Source: (Gromball, 2019)

From the data we processed, Industry 4.0 made various activities improve. Just mention the quality of the sugar produced, errors and waste. The quality of sugar produced will be much better if we compare it with the manual method carried out by factories based on the old system. Because with the method we use when production is in progress, we start the production process using a computer and we have applied the standardization to the computers we use and are on target. Then, optimizing energy consumption is the use of appropriate energy to produce sugar from raw materials into finished goods. The system that we put into all types of sensors will read a lot of the energy we need and in any sector that requires energy that does not require energy at the same time. Of course, the optimization of energy consumption will make factories spending less and increase the profit of our sugar factory. Also, no less important is environmentally friendly. We can use all kinds of waste from sugar production again for the needs of the surrounding community. Like sugar cane which must be extracted into sugar.

we will use this sugar cane as a natural fertilizer and re-use it to fertilize the sugar cane tree. By having a smart micro-factory in a plantation, we would be able to give back the community by having them process the sugar directly and through a smart process. By having digital leadership, Indonesia could move into a bigger and smarter industry scale. The waste of sugar products such as bagasse and filter cake could turn into biofuel. Other than that, having a Micro-Factory optimizes the process of sugar production. For example, in quality control, we will have people manually check the sugar granules or the moisture content by checking them through a lab and that takes time and effort. Using IoT, the idea is to automate that kind of process that will speed up such activity. By having machines communicating with other machines or controlling from a different place, we will have a fully functioning micro-factory 4,0 of sugar production.

Sugar Production Micro-Factory 4.0 Strategy Options

The strategy of implementing IoT and the Additive Manufacturing value loop to a sugar production is by step 1 of the course which is digital leadership. Other than telling the community on moving forward to an industry 4.0 era, digital leadership, in this case, could also mean solving the problems of operational control in sugar. Back then, the sugar production control is complicated but with having micro-factory the Industry 4.0 sugar plant operation control will have wider oversee capabilities and easier to use. So again, the process of sugar production starting from juice extraction until packaging will have a smaller area because of smart implementation to it. Other than operational effectiveness, the sugar micro-factory also gives a strategic positioning. It creates a unique competitive position by doing things differently to deliver distinctive value. The strategic goals of sugar producers are simple: to provide competitive products, boost profitability and grow their business in a climate of increasing globalization and elevated product development costs. (ABB, 2018)

In reaching these goals, every sugar producer faces specific manufacturing challenges, yet there are several that are familiar across the industry including the need to:

- optimize energy consumption
- reduce material use and inventory costs
- increase asset utilization and throughput
- improve quality and reduce variations, errors, and waste
- maximize material traceability and fulfill regulatory compliance
- embrace an agile manufacturing environment

Digitalization helps build a solid platform for process data collection. This addresses vertical integration by making sure process data are utilized for management decisions across the plant. Horizontal integration plugs the plant into the digital world, connecting suppliers and customers.

Operational Effectiveness with Automation

As mentioned before, the strategy options of Micro-Factory 4.0 have operational effectiveness by assimilating and extending best practices by getting to the productivity frontier. So, by improving existing production IT, of course, there will be a problem in digital leadership. The realization challenges include system challenges in data acquisition and verification, alarm management, optimization and control loops, integrated data management, and predictive analytics. The system scope of automation will be like the graph below (ABB, 2018);

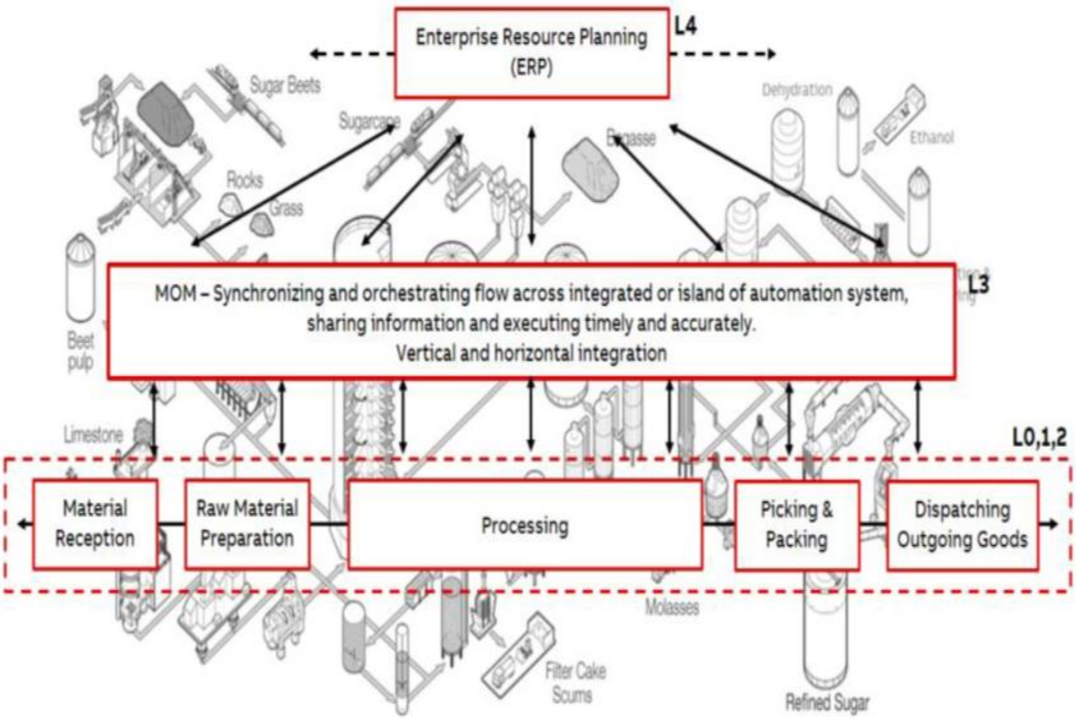

Figure 4: Scope of Automation
Source: (ABB, 2018)

So, using automation the scope will be the 5 levels as mentioned above in the automation subsection. Moving on to the ideation where there are application levels. Using the production toolbox of industry 4.0, we can see the gap analysis production. The application levels include:

- Data processing in production
- Machine to machine communication
- Company-wide networking with the production
- ICT infrastructure in production
- Human-machine interfaces
- Efficient for small batches

There will also be optimization in production monitoring and control system design. Using the pyramid of IT, it could automate from the field level up to the business level using ERP. The other idea is to implement an MES or manufacturing execution system that analyses and controls various elements of the production process. This helps decision-makers understand how existing conditions in each plant can be optimized to improve output. This is where the Manufacturing Operations Management (MOM) solution comes into play. MOM is a comprehensive, scalable and modular suite that encompasses process intelligence, manufacturing execution, production intelligence, and production optimization.

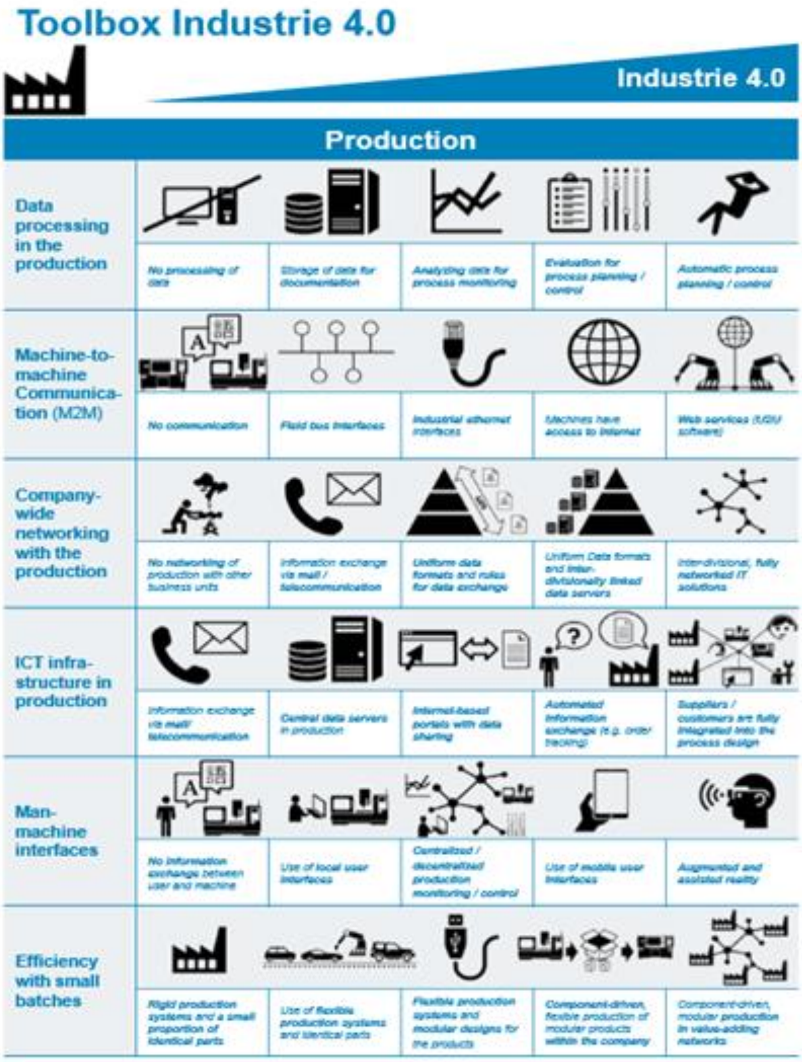

Figure 5: Industry 4.0 Toolbox
Source: (VDMA Verlag)

MOM undertakes historical trend analysis and key performance indicators. MOM brings end-to-end visibility into an entire sugar production process. It is a scalable and modular suite that extends across:

- Process intelligence
- Manufacturing execution
- Production intelligence
- Production optimization

The table below summarizes the challenges, features and benefits of the Manufacturing Operation Module (MOM);

Challenge	Features and benefits
Improve resources utilization (productivity, efficiency)	• Real-time overview of the material usage and inventory/WIP • Machines and equipment utilization in the context • Real-time production status and deviations
Reduce error and variation (waste)	• Defined workflows and exception handling – in-process quality control • Electronic work instructions and checklists • Trained and certified operators • Paperless manufacturing

Challenge	Features and benefits
Facilitate continuous improvements	• Systematic collection, visualization, and analysis of quality test records, deviations, and non-conformances • Downtime and interruptions • Operator knowledge
Enable agile manufacturing	• Ease of introducing new products and processes • Responsiveness to customer change • Remove production constraints, control buffers • Integration with engineering and design solutions

Table 1: Impact of MOM in Sugar Production
Source: (ABB, 2018)

So, the realization of using IT automation has 6 roadmaps that come together into the implementation plan. First, we must define the vision and strategy of automation. Elaborate manufacturing IT vision and strategy. Define, align and prioritize those tasks. Second, is the assessment for MES and SOR (statement of requirement). We assess the functional specification of the manufacturing process, draft the recommendation on how to distribute processes and weight selection criteria for the appropriate MES product. The third is the cross-functional and cross entity SOR. We align the SOR outcome with all stakeholders and get the cross-functional approval for the continuation. Fourth it MES vendor and Product selection, we ask selected MES vendors to demo the functional specification and evaluate the vendor response. By then select the preferred product. The fifth is the preparation and finalization phase. We align between sites in scope, check plant implementation readiness, conduct training, and finally get final approval. Last is the pilot plant MES implementation phase where we conduct detailed requirement analysis for development specifications.

Operational Effectiveness with cloud-based smart factory

So, this is another way to improve operational effectiveness which is to move to cloud computing. The idea is to have a cloud computing strategy where each data could be easily extracted by machine to machine. Instead of 5 level factory automation pyramids using MES and others, cloud-based computing to a highly flexible connected cloud-based smart factory using a computerized numeral controller.

The basic smart factory architecture includes the Things, connected through the fog and finally the cloud. The production monitoring and control system design will be using digital twin. It enables manufacturers to overlay the virtual digital product on top of any physical product at any stage of production and analyze the behavior. Now manufacturers can have the complete digital footprint of the entire plant. The system module should be different as well because of course back to the idea generation where we want a machine to communicate with each other by having the data uploaded and downloaded through the cloud, so the system modules must support that kind of interaction. The other thing that must be implemented is the maintenance system. Applying predictive maintenance technologies could help in vibration analysis and oil analysis.

Figure 6: Smart Factory Architecture
Source: (Gromball, 2019)

Also, we can make energy usage optimization. As we know, electrical and steam consumption among the sugar industry’s biggest costs, there are many energy-saving opportunities. Steam consumption, for instance, can be calculated, monitored and controlled to match the actual demand of individual parts of the plant.

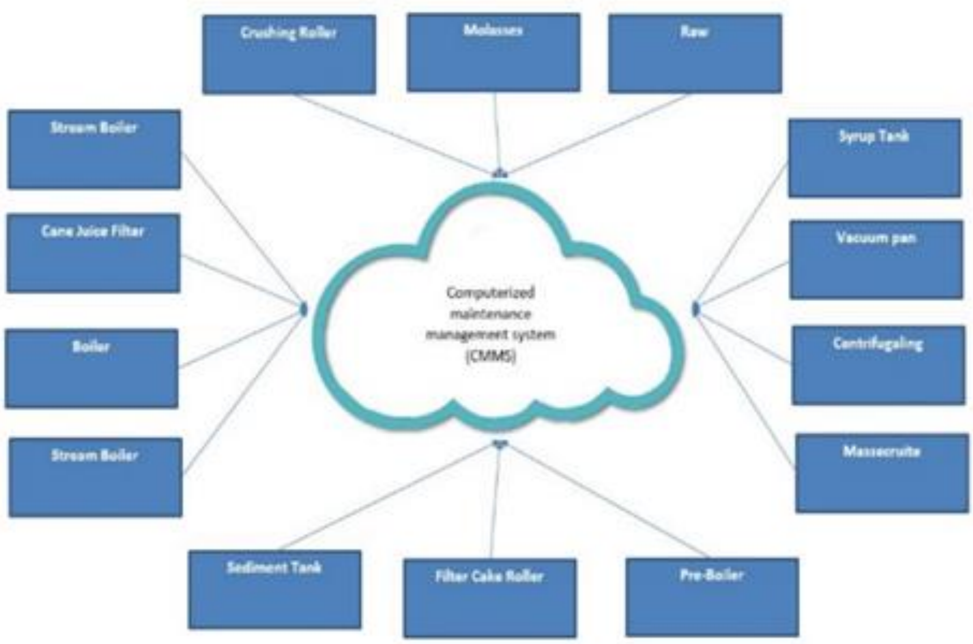

Figure 7: Computerized Maintenance Management Systems
Source: (Gromball, 2019)

This can have a direct impact on the overall energy consumption, resulting in a 20 percent reduction. Other than maintenance, the bigger part is analysis. So, as we discussed above that the sugar quality control must be tested by a person. If the quality data could be uploaded independently by the machine to the cloud so if there is something wrong, the cloud could analyze what is wrong and how to improve it. That will be autonomous in away. Other than quality control, waste could also be analyzed. So, the utilization of cloud-based computing might improve operations and enable lean and/or agile manufacturing. The outcomes of this will consistent volumes and quality as production risks reduced, fewer decision-makers needed, reduced operating cost, better management of a plant's asset capacity, substantial improvements in the whole supply chain efficiency.

Strategic Positioning with Micro-Plants 4.0

Again, by having micro-factory 4.0 it will give an edge over competitors in many ways. Also, it will improve company social responsibility as well. Other than the more productive sites and cheaper cost of production, by doing things differently it will make a marketing advantage of some kind. It will transform how business goes, it will be like a farm to table dining restaurant but instead of the restaurant, we have a factory from farmers directly into the hands of the consumer. Even better, the customer could control or oversee our production using the virtual factory that will be enabled. With the same quality and unique way of delivering value, the consumer will position the product better than the competitors.

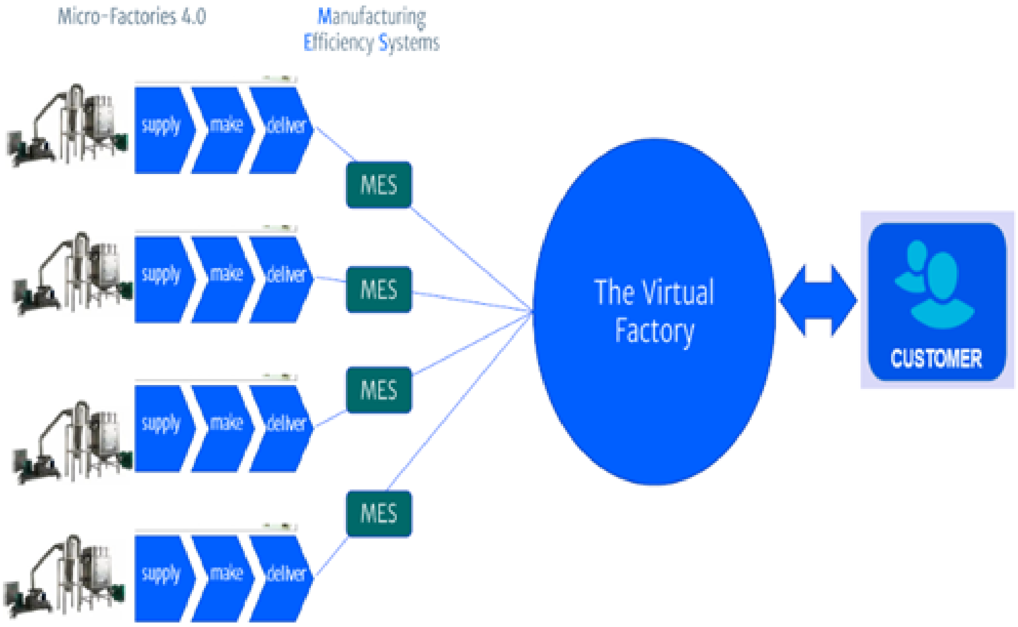

Figure 8: Scaling of Production
Source: (Gromball, 2019)

Conclusion

In conclusion, we are implementing the cloud-based micro-factory instead of automation even though both give us a better process optimization. Having automation, it is common in other types of manufacturing, but cloud-based micro-factory is amazing to implement to sugar production as it will give the factory an advantage over the competitors as well. In the end, the data analyzing of the quality, maintenance, etc is effective as it should be. Artificial Intelligence and the Internet of Things give us that kind of technology so that we can implement the M2M (machine to machine) with data processing at a very high-speed process. Not just improving the process, at the end of the day, micro-factory will have smaller plant area than regular or automated sugar production.

Overall, this course gave us an opportunity to learn IoT, Micro-Factory, and business that can be implemented using this kind of new strategy and technologies. This report will give a better understanding of the PowerPoint that Dr. Gromball helps us interpret our idea of sugar production micro-factory.

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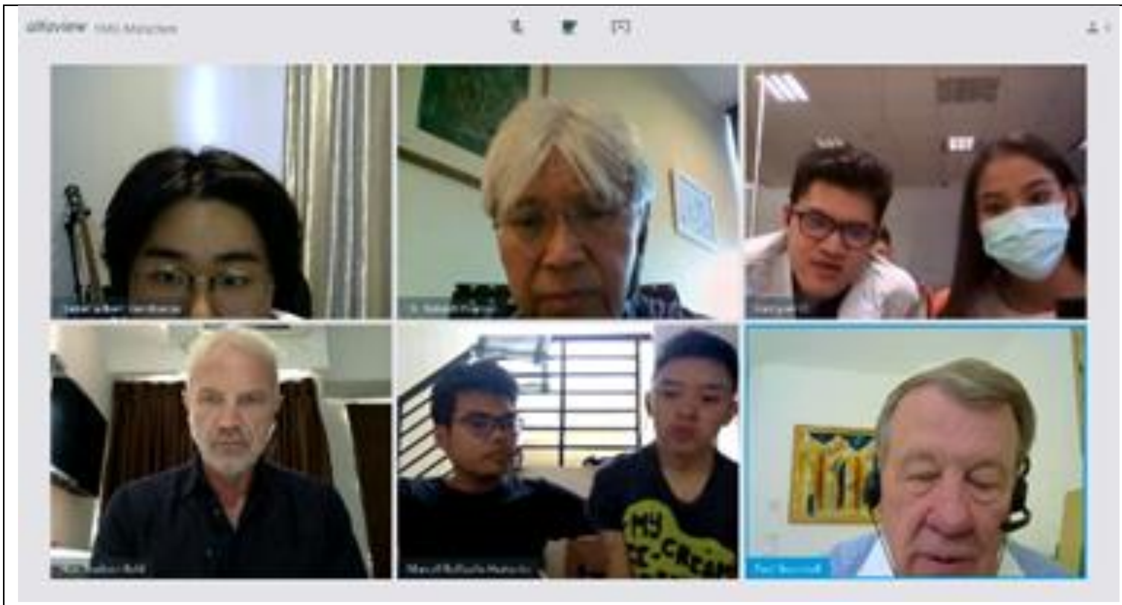
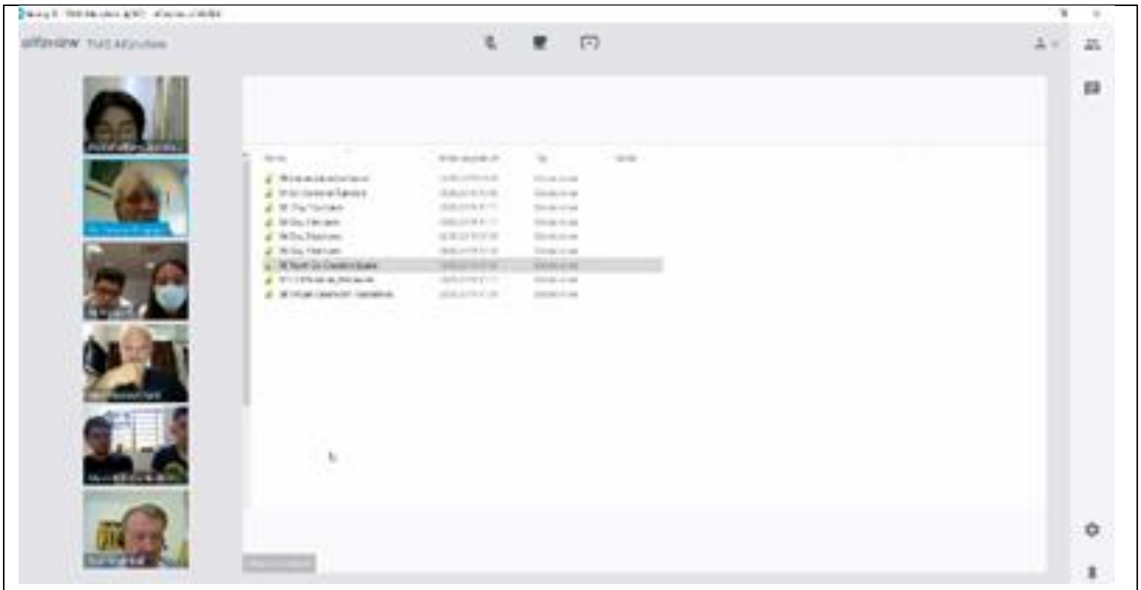
Appendices



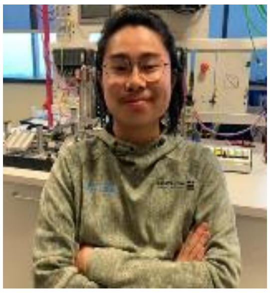



Analyze Target market segment
Increasing Sugar Production in Indonesia through Land Suitability Analysis and Sugar Mill Restructuring
Indonesia Industrie 4.0 Portfolio
Challenges & Solutions
Analysis of the situation
Problem Identification
Resolution
Programs & Strategies
Sugar Production & Consumption Trend analysis
Planting area
Sugarcane varieties
Sugar mills
Figure 1. Framework used to examine methods to increase sugar production in Indonesia.

The Authors

(left to right: Dwi, Hamy, Sonya, Marcell & Daniel)

1. **Daniel Wilbert Hendrason** is now a 3rd year students in International University Liaison Indonesia (IULI) majoring in Industrial Engineering. Since high school he has been participating in academic and non-academic activities, such as; e-sports cup, math and chemistry competitions. In college he has been an active member of organizations. He was the chairman of Catholic Student association of IULI and the vice chairman of an event holding 16 different universities. He is now the chairman of the industrial engineering student board. He once received a scholarship by the university awarding him for the good GPA. Daniel could be contacted by email: danielhendrason@gmail.com

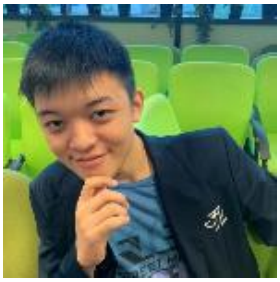


2. **Dwi Cahyo Wibowo** is currently taking a concentration in Industrial Engineering. Since high school, he has been actively involved in student and student organizations. Various achievements I have made in high school, such as the 2003 GPMB at Senayan, Porprov 2010 in Bontang, East Kalimantan, PON XVII in Balikpapan East Kalimantan, the 2011 Marching Show Band World Championship in Malaysia and many more. I can be contacted via email: dwii.cahyow@yahoo.com

3. **Hamyrez J. Oszarwin** currently is a student in Industrial Engineering in International University Liaison Indonesia (IULI). He is a part of the industrial engineering student association in IULI. He also gets involves in several non-academic activities such as being a volleyball member and first aid member during high school. While for the current achievement in IULI are being; second place for mobile legend in the first

year of IULI's internal competition and first place in the second year of IULI's internal competition. He also took part in participating in several of IULI's organization activity such as being a committee during the October festival, Internal competition, Kartini day, and event chairman for new college student orientation. Hamyrez can be contacted via email: oszarwin@gmail.com

4. **Marcell R. Hartanto** is an Industrial Engineering student in IULI. He is the vice-chairman of the industrial community. He also achieves some non-academic such as the first place in a basketball competition at junior high, third place in futsal competition at high school and second place for mobile legend in the first year of internal competition and first place in the second year of internal competition both at university. He was also active in the organization at high school such as became a mentor for high school orientation, become the committee of the Permai cup of basketball competition. Marcell can be contacted via email: marcellraffaello@gmail.com



5. **Sonya Indriastuti** is currently undergoing a bachelor-degree in IULI since 2017majoring in Industrial Engineering. Sonya is actively involved in student organizations, one of which is the Student Executive Board (BEM) by serving as the Chief Secretary and the Student Consultative Assembly (MPM) by serving as a member of the Public Relations division. Sonya is also actively involved in non-academic activities, such as Futsal, Basketball and Badminton. Sonya can be contacted via email: anyasonya56@gmail.com

The Facilitators & Editors

Dr. Ir. Prianggada Indra Tanaya is currently serving as the Dean of the Faculty of Engineering at International University Liaison Indonesia (IULI). He has completed his bachelor degree in Mechanical Engineering from Institut Teknologi Bandung, a master degree in Production Engineering, and a doctoral degree in Production and Automation form Katholieke Universiteit in Leuven, Belgium. He has engaged in teaching activities in various subjects in the Department of Industrial Engineering, Mechanical Engineering, and Mechatronics. He is also actively involved as the scientific committee members of international conferences, such as; the International Conference in Mechatronics and Mechanical Engineering, International Conference on Aerospace, Mechanical and Mechatronics Engineering, and an International Conference Mechatronics, Robotics and Systems Engineering. Scientific research papers have been published in the fields of autonomous robotics, bipedal robots, and modelling and simulation of robots. He can be contacted via email: prianggadaitanaya@gmail.com

Dr. Samuel PD Anantadjaya is currently serving as the Dean of the Faculty of Business & Social Sciences at the International University Liaison Indonesia (IULI) since August 2015. He holds a Bachelor of Science (BSc) in Finance & Economics, a Master of Business Administration (MBA) in Finance, a Magister Manajemen (MM) in Strategic Management, and a doctoral degree (Dr) in Strategic Management with a concentration in

Organizational Performance Management and Control Systems. In addition, he also holds certifications in Financial Planner, Financial Consultant, and Business Administrators. He can be contacted via email: spdanantadjaya@gmail.com

Dr (cand) Irma M. Nawangwulan, MBA, CPM (Asia) is now acting as the senior lecturer in IULI's Department of Hotel & Tourism Management. She holds academic degrees from USA; Bachelor of Science in Management, and a Master of Business Administration, and a professional certification as the Certified Professional Marketer (CPM) for the Asian region. She is currently pursuing her doctoral degree in Management. She has also engaged in numerous appointments in USA and Indonesia with the University of Wisconsin Systems, Boston Store, Mincom Services, Carrefour, Ace Hardware, ETC & Foundation. Her passions are in the fields of consumer behavior, customer intimacy, experiential marketing, service delivery, customer relationship management, customer value and trust. She can be contacted via email: mnwulan@gmail.com