

WORKPLACE AUTOMATION AND EMPLOYEE PERFORMANCE**Oguzo, Ndubuisi****PhD Student, Department of Business Education
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Port Harcourt, Rivers State, Nigeria****ABSTRACT**

The ability to save time and money in the workplace has been a very crucial and critical factor to any organization's administrative needs. Today the global market is changing to increased competition, short product life cycles and mass customisation. Workplace automation" is generally considered to refer to the use of integrated computer and communications systems to support administrative procedures in a workplace environment. Considering the volume of work in the Universities where there is a pressing need to develop quicker and more efficient admission management systems, results computation systems, data management systems, teleconferencing, meeting schedules, monitoring of employee performance, intranets, electronic mailing systems, etc. automation is the key if productivity is to be enhanced in such situations. However, despite the enormous benefits of automation in the workplace, it was observed that together with its benefits are a couple of challenges facing workplace automation. Employee satisfaction, fear of being replaced, Employment and wages, and Transition posed itself as some of the challenges rocking workplace automation in most organizations. This study investigated the effect of workplace automation on employees. On-the-job Training, Off-the-Job Training, Mentoring, Coaching, and willingness to learn, seminars, and creating of public awareness were recommended as strategies to improve employee transition towards workplace automation.

Keywords: Workplace Automation, Artificial Intelligence, Robots, Employee Performance, Change Management

INTRODUCTION

The rate at which changes have been taking place in all facets of human life including the workplace is lightning fast. Every workplace today, whether public or private are in desperate need of facts and accurate information for quick decision-making and accurate job deliveries. Without workplace automation, work may be slowed down therefore lowering employee performance and productivity of workers. The nature of workplace today in terms of correspondence handling and workflow is totally different from time past. Today, robots are employed to make office work faster and easier, hence the relevance of workplace automation in the operation of organizations cannot be overemphasized (Clavecilla&Villaflor, 2016). Workplace automation enable organizations gain critical competitive edge over contemporaries (International Federation of Robotics IFR, 2017) especially now that there are a lot of changes in the global economy (Azma, Izanlou&Mostafapour, 2012) as these machines/robots improve organizational efficiency and effectiveness through easy flow of correspondence, quick access to stored data, as well as making record-keeping effective by aiding easy retrieval (Barakat, 2014).

Without the relevant workplace automation, which is the adoption of electronic devices to carry out office functions in order to improve efficiency (Esene, 2012), employee performance may be adversely affected. Employee performance comprises those work related activities expected of an employee and how well those activities are carried out (Business Dictionary, 2014). However, despite the long list of benefits automation brings to the workplace, several studies stress on the need to develop on change management strategies. To facilitate the transition, management support is considered to be vital (Hayes, 2014). Scherrer-Rathje et al. (2009) also believe that management support is an essential condition for success to be achieved in an automated

workplace environment. Thus, this study makes a diligent research on the relevance of workplace automation, with focus on Tertiary Institutions Administration and its effect on their employees.

Concept of Workplace automation

According to Canning (1978), the term "workplace automation" is generally considered to involve the use of integrated computer and communications systems to support administrative procedures in an office environment. Automated workplace systems usually represent structured methods of handling business text processing and communications through an integrated network that may include word processing for generating correspondence, electronic message systems for person-to-person communication, teleconferencing and video conferencing services, facsimile transmission, electronic filing systems, on-line calendar systems, e-payment systems and other services (Canning, 1978). Carlisle and James (1978) posits that the concept of workplace automation will not only make works faster, more efficient and accurate, but the concept of office work itself will be altered. They further added that the greatest potential of workplace automation is not expected to be from the improvement of clerical and administrative tasks, but from the ability of managers to gain increased control over their operations (Carlisle and James, 1978).

Idowu (2002) reports that the history of workplace automation started with the invention of the typewriter and the copy machine, which was used to handle tasks in a mechanized way (Idowu, 2005). However, today's workplace automation has metamorphosed from mechanization of tasks to the conversion of information to electronic form. Its introduction into the work environment have reshaped the entire workplace system with both beneficial and adverse effects on employees (Maria, 2019). The term workplace automation refers to all tools and methods that are applied to office activities which make it possible to process written, visual, and sound data in a computer-aided manner (Idowu, 2005). Workplace automation is intended to provide elements which make it possible to simplify, improve, and automate the organization of the activities of a company or a group of people (management of administrative data, synchronization of meetings, etc.). Workplace automation is composed of the varied computer machinery and software used to digitally create, collect, store, manipulate, and relay office information needed for attaining basic tasks. Raw data storage, electronic transfer, and the management of electronic business information comprise the basic activities of a workplace automation system. According to Nwosu, (2000), workplace automation helps in optimizing or automating existing office procedures especially since it employs the use of computerized technology such as computers, copy machines, printers, scanners etc to increase organizational effectiveness (Kimutai & Kwambai, 2017). This implies that organizational effectiveness as well as performance depends totally on the level of workplace automation utilized by such organization.

Workplace Automation and Employee Performance

In organizations, workers usually expect to be provided with the necessary tools that will enable them carry out their duties efficiently and timely. Robots in the form of machines and electronics are necessary to complete tasks. In the past, memo's and letters were dictated by managers but recently, business correspondence and functions are carried out with word processors with heavy reliance on personal computers and workplace automation including electronic mail so as to lessen the need for more staff and make the available workers very productive (Osuala, 2004). In today's office, workers are exposed to office technology including the internet that make work much easier and knowledge more accessible making it faster and easier to send messages by telex, electronic mails (e-mails), fax and telephones (Edwin, 2008). With the trend of events, for employees to be relevant in today's business world, there is need for them to be versed in the use of workplace automation (Agboola, (2003). To enhance performance therefore, workers themselves need to understand that technology is not static, hence workers need to acquire additional training to keep abreast of the new trends since Clavecilla and Villafior (2016) have rightly opined that workplace

automation help employees complete their routine, repetitive and tasking duties which have positive impact on their employee performance.

Employee Performance

Employee performance as a concept have been described by various authors in different ways. Moshref and Delshad (2011) defined employee performance as the achievement of set goals in terms of quality and quantity. According to Oxford Dictionary of English, employee performance is the act of performing, applying or executing anything organized or promised. From this definition, performance means doing an activity and the outcome of that action. It can also be viewed as the shared performance of effort, ability and role understanding (Milis and Mercken, 2004) while Shoji and Valden (2008) assert that performance is wider as it incorporates behaviours as well as results. While behaviours are responsible for changing performance from a thought into an action, results are consequences of mental and physical activities. Varying from Shoji and Valden (2008) is Jex and Britt (2008) and Campbell (1990) who see performance as only the controllable behaviours of employees and not outcomes since according to them, employees can put efforts but circumstances beyond their control such as a dysfunctional system may limit the outcome of their efforts. Apart from a dysfunctional system impacting negatively on employee performance of employees, any organization that refuses to introduce these machines, may not meet up with the challenges of modern day office, hence productivity may be reduced (Maria, 2019). Employee performance is the assessment of whether an employee has done his job well or not. It is the degree of accomplishment of the tasks that make up an employees' job (Ahmad, Nadeem&Hamad, 2014).

Benefits of Workplace Automation in Tertiary Institutions

According to Christiana (2008), workplace automation plays a vital role in supporting powerful, efficient management and administration in the educational sector because technology can be used right from student administration to various administrative areas in an education institution. Hossein (2008) lends credence to Christiana's view that workplace automation provides several possibilities for educational administrators to do their tasks and some of the critical needs of management in tertiary schools includes the student admission process, e-payment/bursary management system, preparation of student's transcripts/grading system and employee management processes. The integration of ICT enhances the overall admission activities of higher education institutions by making it more accessible to many (Thomas, 2004).

The transition from manual to online applications, registration, scoring of scripts, and collating and disseminating of results improves the efficiency, accuracy and reliability of admission procedures (Nosiri, 2005). Mbakwem and Okeke (2007) stated that such a transition guarantees safety, security and efficiency in handing large volumes of scores over a very short period.

Online registration is a recent technology in school administration via e-management. Before the advent of on-line registration, students were faced with a monotonous task of manual registration of courses where they were faced with all manner of intimidation and wrong attitude from staff who are supposed to sign such forms. Ajayi (2004) noted that this method was cumbersome and time wasting. The idea of online registration is however in line with the world's latest trend of information technology prior to the advent of e-management in Nigerian universities. The online registration system allows students, to register through the internet, and drop or add courses online within the registration period. The students are expected to go into a cybercafé or any available internet facility and log into the school website and register courses for the semester/session. Ashish and Arun (2005) and Ajayi (2004) stated that on-line registration has put an end to all manners of complaints by students about the nonchalant attitude of some staff in signing course forms as experienced in manual registration, and also allows quicker response. In the same vein, Chaoes (2006) also noted that a well-conceived and implemented automated

student record system can reduce the cost of handling the paper work associated with record keeping.

Another very important service delivered by the Student Affairs Unit has to do with the arrangement for hostel accommodation. Onyeagbako (2002) maintained that manual method of managing and administering hostels in institutions is obviously not effective as it is attributed to drawbacks like human error, low security, difficulty in data update, and difficulty in record keeping. Kola (2014) then submitted that the easiest way to address the drawbacks of the manual scheduling methods and ensures data integrity especially in a thick populated institution is to make access to accommodation electronic and online.

Negative Impact of Workplace Automation on Employee Performance

- Employment and wages

Sachs and Kotlikoff (2012) present a simple framework in which smart machines substitute directly for young unskilled labor, whereas they are complementary to older skilled workers. Young unskilled workers experience lower wages, which in turn lead to lower saving and investments in human and physical capital—thus perpetuating and strengthening the gap between young unskilled and older skilled workers over time. Historically speaking, Autor (2015) and Mokyr et al. (2015) argue that, as in other times in history, technological progress will lead to major structural changes in the quantity and content of work, but it will arguably not lead to a complete substitution of capital for labor. More recently, McGuinness et al. (2019) and Klenert et al. (2020) present empirical studies that indicate that automation technologies and industrial robots have actually positive effects on employment. However, he included that automation leads to a creative destruction process that may on the whole increase the overall demand for labor.

Middle-skilled workers are those more negatively affected by routine-biased technical change, because their tasks are relatively easier to automate. As for low-skilled workers, and particularly those employed in personal services occupations, these often perform manual and personal communication tasks that are not that easy to automate yet. Hence, the resulting pattern is that middle-skilled workers have in recent years shifted towards low-skilled employment occupations, which have consequently grown and experienced higher wages. All in all, this explains the observed increasing polarization in the job market, with the growth of employment and wages for high- and low-skilled workers, and a corresponding decline for middle-skilled occupations (Blanas et al., 2020). Beaudry et al. (2016) argue however that the demand for high-skilled workers has declined after 2000 due to decreasing returns to investments in information and communication technologies (ICTs), and that high-skilled have then begun to compete for lower-skilled jobs. This study, though, is based on empirical evidence on ICT investments in general, and it does not focus specifically on the effects of AI and automation.

Acemoglu and Restrepo (2020), in their study presented a theoretical framework that is useful to study both negative and positive effects of industrial robots on employment and wages. The model points out two contrasting effects of industrial automation: a *displacement* effect that negatively affects the demand for employment and the wages of workers that perform routine-based tasks; and a *productivity* effect that creates benefits for workers that perform non-routine tasks (in the automated sector as well as in other sectors and occupations of the economy).

- Employee Satisfaction

Employee satisfaction is the subjective well-being of workers (i.e. their own assessment of the well-being they experience at work). This is an obviously sacrosanct dimension for economic analysis and policy. Based on the fact that individuals spend a substantial part of their life at work, job satisfaction experienced in working life represents an important component of individuals' overall subjective well-being. It is observed that workers who are not happy and experience dissatisfaction with their job have typically lower motivation and efforts, and higher turnover rates. This, in turn, weakens productivity and innovation in the economy. Kaplan and Schulhofer-Wohl (2018), using data from the American Time Use survey, discusses the nonpecuniary implications

of changes in the occupational structure in the US in recent decades, i.e. the effects of these structural changes on different aspects of job satisfaction such as reported happiness, stress and meaning at work. The work indicates that the changing occupational structure has not only led to polarization in terms of skills and wages, but it has also determined substantial changes in workers' feelings about the job they have and the tasks they perform.

Recently, research has been ongoing on the relationship between automation and workers' well-being. Abeliasky and Beulmann (2019) presented an empirical study on the impact of automation on the mental health of workers (which is one important dimension reflecting stress and weak job satisfaction). The analysis uses individual-level data from the German Socioeconomic Panel for the period 2002–2014 linked to industry-level data on use of industrial robots in 21 manufacturing sectors in Germany. The results indicate that automation negatively affects workers' mental health, and this effect is related to the fear of having lower wages and worse economic conditions in the future.

- **Fear of Replacement**

The introduction of industrial robots in the local labor market increases the likelihood that some workers will be replaced by smart machines in the future. These technological changes and their applications in firms in local labor markets will therefore induce some workers that are currently employed to fear that they might be replaced in the future (or at least that some of their tasks might be).

Theoretical Framework

The main theoretical areas related to this research include; Workplace Automation and Change Management.

- **Change Management**

The rate of change is rapidly escalating in all organisations to remain competitive as suppliers of services and goods to the larger organisation and at the macro level. The phenomenon of change is considered evidence to survive; therefore, many theories stress the importance of managing the change efficiently and effectively. Thomas et al. (2011) described the change as a common, ongoing, and anticipated process. The volatile and ever-changing global environment urges organisations to develop the capability to adapt and change (Abrell-Vogel & Rowold, 2014). If themed by being rapid, efficient, and continual, this capability to adapt and change will distinguish the winners from the losers in today's rapidly changing, highly competitive environment (Lorenzi & Riley, 2000).

Lorenzi & Riley (2000) define change management as "the process by which an organisation gets to its future state, its vision." Lorenzi & Riley (2000) first stressed creating a vision, then encouraging individuals to change agents to achieve that vision. Moreover, Lorenzi & Riley (2000) also characterises the plans needed by these change agents: realistic, future-oriented, providing a total systems approach. According to Lorenzi & Riley (2000), change in an organisation is often identified as one of four types: operational changes, strategic changes, cultural changes, political changes. Operational changes target how the business's ongoing operations are done, for example, the Automation of a particular area. Each of these types has its impact at a different level of the organisation; for example, operational changes have their biggest effect at the organisation's lower level (Lorenzi & Riley, 2000). In some cases, change is accompanied by something called resistance to change. Resistance to change is described as the refusal to adapt to altered circumstances, which can be organised, overt or covert, or individual (Coch & French, 1948). In all three cases, resistance to change is considered to be disruptive (Coch & French, 1948).

- **Kotter's model of change:**

Change is never easy, and studies of large-scale organisational change show many difficulties as it can be time, energy, and attention consuming. However, through understanding the change

process and applying that knowledge to manage and lead the change, the results can be improved (Ates&Bititci, 2011). This includes a comprehensive understanding of the steps needed to be taken for the process to be successful (Kotter, 1995). Kotter (1995) also suggested a model to facilitate change in the organisation. This model is comprised of eight stages that an organisation should go through. Each stage must be adequately addressed if the required change is to happen and come to be part of a new operating environment. These stages are explained and shown in table 5. However, this model was criticised by (Kesken&Ilic, 2008) for deficient understanding certain aspects of human nature and its psychological reaction to change. Moreover, Kesken&Ilic (2008) argued that the model should provide a balanced message of the advantages and disadvantages of change.

- **Workplace Automation**

Automation is defined by the Oxford Dictionary of Mechanical Engineering (2019) as "*Mechanisms and systems that reduce or eliminate human labour; often applied specifically to manufacture and inspection on production lines*" (Atkins &Escudier, 2019, p. 395). A frequently used form of automation are Robots (Atkins &Escudier, 2019). Robotic applications can be distinguished between flexible or fixed solutions (traditional). The traditional solution is mainly installed in automobile industries with around 65 % according to Djuric et al. (2016). These can be explained by the properties of traditional robotic applications, which require a lot of space, complex and timeconsuming programming (Andersson et al., 2020). Besides, they are fixed installed, only profitable with medium to large lot sizes, and used for periodic repeatable tasks which infrequently are changed (Andersson et al., 2020; Djuric et al., 2016). On the other hand, flexible solutions for instance, collaborative robots (CoBot), are mostly easy to program and lightweight, besides also without guards usable, intrinsic safe, slow in a collaborative operation, and they are able to work with humans at the same task (Andersson et al., 2020; Matheson et al., 2019). Additionally, they are usable for assembly, pick and place applications. However, compared to a traditional solution, a CoBot solution delivers worse results in terms of speed, precision, and payload (Andersson et al., 2020; Matheson et al., 2019).

The characteristics of traditional robotic solutions contradict today's market development, which demands reduced lead times, mass customisation, and fast product changeover (Matheson et al., 2019). Production companies and their manufacturing systems are required to be flexible, fast and easily changeable, and already cost-efficient with low volume to serve the changing market (Zheng et al., 2019). The term flexibility has received a lot of attention during the last few years from both the SME industry and academia due to external factors such as changing consumer preferences and increased competition (Wadhwa, 2012). The fast-changing demands require the manufacturer to be more flexible on the production and product level (Wadhwa, 2012). The production flexibility of a company is the ability to compete in a market that has a fast and frequently changing demand, which requires to have short implementation times for new and major modified products (Wadhwa, 2012). In contrast, "*product flexibility relates to the ability of the system to cope with changes products to be processed by the system*" (Wadhwa, 2012, p. 448). As stated by Wadhwa (2012), most often, product flexibility is used to achieve flexibility in a manufacturing system. The product flexibility can be increased with a focus at the machine or system level. Thereby according to Wadhwa (2012), flexibility at the machine level is the basic framework for other flexibilities.

CONCLUSION

The lightning pace of introduction of computerized systems in various workplaces in recent years represents a new major process, which Schwabe (2019) refers to as "Schumpeterian creative destruction". This process will in the near future lead to dramatic consequences for employment in many sectors and regions, and it will at the same time create new unprecedented opportunities

for productivity growth, wealth and well-being. Authors argue that transitions relating to workplace automation will not be smooth and swift: it will unfold over a period of several years, and it will lead to important negative impacts in the short-run before the long-run economic and societal benefits will eventually emerge, of which fear of being replaced, employee satisfaction, and employee performance have been highlighted areas of issues.

RECOMMENDATIONS

Considering the volume of work in the Universities, automation is the key if productivity is to be enhanced. Hence, management should provide fund for the procurement of these needed machines/gadgets in their right quantities and qualities and at the right time. Moreover, getting the right equipment and gadgets is not enough. There is constant need for management to ensure that the following is put to assure proper transition from manual to automated workplaces;

- On-the-Job Training
- Off the Job Training
- Conduct Seminars from time to time
- Employees should also be encouraged to show willingness towards the use of these machines to improve on their jobs.
- Coaching
- Mentoring

REFERENCES

- Acemoglu D. & Restrepo P., Robots and Jobs: Evidence from US Labor Markets. *Journal of Political Economy*, 2020. 128(6): p. 2188–2244.
- Ajayi, S.O. (2004). *Information technology*. Ibadan: Spectrum Books Ltd.
- Andersson, S. K. L., Granlund, A., Hedelind, M., & Bruch, J. (2020). Exploring the Capabilities of Industrial Collaborative Robot Applications. In *Advances in Transdisciplinary Engineering* (Vol. 13, pp. 109–118).
<https://doi.org/10.3233/ATDE200148>
- Arntz, M., Gregory, T. and Zierahn, U. (2016), "The Risk of Automation for Jobs in OECD Countries", *OECD Social, Employment and Migration Working Papers*, No. 189, OECD Publishing, Paris.
- Ashish, K. & Arun, K. (2005). IT based KM for institutions of higher education. Paper published in a weekly in India from Association of Indian Universities. New Delhi India, 43(30), 110-129.
- Atkins, T., & Escudier, M. (2019). *A Dictionary of Mechanical Engineering* (2nd ed.). Oxford University Press.
- Autor D.H., Why Are There Still So Many Jobs? The History and Future of Workplace Automation. *Journal of Economic Perspectives*, 2015. 29(3): p. 3–30.
- Autor, D.H. (2013), "The 'Task Approach' to Labor Markets: An Overview.", *Journal for Labour Market Research*, Vol. 46 No. 3, pp. 185–199.
- Autor, D.H. (2013), "The 'Task Approach' to Labor Markets: An Overview.", *Journal for Labour Market Research*, Vol. 46 No. 3, pp. 185–199.

- Beaudry P., Green D.A. and Sand B.M., The great reversal in the demand for skill and cognitive tasks. *Journal of Labor Economics*, 2016. 34(S1): p. S199–S247.
- Blanas S., Gancia G. and Lee S.Y.T.. (2019). Who is afraid of machines? Barcelone GSE Working Paper Series.
- Canning, Richard G. The automated office: Part I. *EDP Analyzer*, 16, 9 (Sept. 1978).
- Carlisle, James H. The management communication and control of office automation. Paper presented at the Infotech State of the Art Conference on Convergence: Computers, Communications, and Office Automation, Paris, France, October 1978. 10
- Chaoes, L. (2006). Database development and management. London, Auerbach Ltd.
- Christiana, M. (2008). Information and communication technology for administration and management of secondary schools in Cyprus. *Journal of Online Learning and Teaching* , 4(3),234-249.
- Clavecilla, R. L & Villafior, M. S. (2016). Impact of office automation on the job performance of employees in Local Government Unit of BAAO, Camarines Sur. Retrieved from: https://www.academia.edu/37001170/Impact_Of_Office_Automation_On_The_Job_Performance_Of_Employees_In_Local_Government_Unit_Of_Baao_Camarines_Sur. Accessed May 13, 2019.
- Djuric, A. M., Rickli, J. L., & Urbanic, R. J. (2016). A Framework for Collaborative Robot (CoBot) Integration in Advanced Manufacturing Systems. *SAE International Journal of Materials and Manufacturing*, 9(2), 457–464. <https://doi.org/10.4271/2016-01-0337>
- Houseman S.N. (2018). Understanding the decline of US manufacturing employment. W.E. Upjohn Institute for Employment Research. Upjohn Institute working paper.
- International Federation of Robotics IFR (2017). Impact of Robotics on productivity, employment and job. Retrieved from: https://ifr.org/img/office/IFR_The_Impact_of_Robots_on_Employment.pdf. Accessed May 11, 2019.
- Kaplan G. & Schulhofer-Wohl S., The Changing (Dis-)Utility of Work. *Journal of Economic Perspectives*, 2018. 32(3): p. 239–58. PMID:30362697
- Klenert, D., E. Fernandez-Macias and J.-I. Anton. (2020). Do robots really destroy jobs? Evidence from Europe. Seville: European Commission. Joint Research Centre.
- List of Universities in Nigeria (2017). Retrieved from: https://en.wikipedia.org/wiki/List_of_tertiary_institutions_in_Ogun_State
- Matheson, E., Minto, R., Zampieri, E. G. G., Faccio, M., & Rosati, G. (2019). Humanrobot collaboration in manufacturing applications: A review. *Robotics*, 9(4), 1–25. <https://doi.org/10.3390/robotics9040100>

- Mbakwem, J.N &Okeke, F.N (2007). Enhancing internal and external quality assurance mechanisms in Nigerian Universities through ICT compliance. *Journal of National Association of Educational Administration and Planning (NAEAP)*. 5(3), 121-136.
- McGuinness, S., K. Pouliakas and P. Redmond, Skills-Displacing Technological Change and Its Impact on Jobs: Challenging Technological Alarmism? IZA Discussion Paper No. 12541, 2019.
- Nosiri, C. (2005). Pupils personnel. A hand book on educational administration. Owerri: New African Publishing Co. Ltd.
- Onyeagbako, J.R. (2002). Micros computer studies for beginners. Onitsha, Spiriton Publishers.
- Sachs, J.D. & L.J. Kotlikoff. (2012). Smart Machines and Long-Term Misery. NBER Working Paper (No. w18629). National Bureau of Economic Research.
- Schwabe, H., Automation, Fear of Replacement and the Subjective Well-Being of Workers. TIK working paper, 2019.
- Shoji, S.H. &Valden, D. (2008). Shortcuts Management. Retrieved from: <https://pdfs.semanticscholar.org/8925/2b58e1b27e720227dbbfd724467662551cfc.pdf>
Accessed January 2018.
- Thomas, K.O. (2004). Practical application of ICT to enhance university education in Ghana. Feature Article, Ghana Web.
- Wadhwa, R. S. (2012). Flexibility in manufacturing automation: A living lab case study of Norwegian metalcasting SMEs. *Journal of Manufacturing Systems*, 31(4), 444–454. <https://doi.org/10.1016/j.jmsy.2012.07.008>
- Zheng, C., Qin, X., Eynard, B., Bai, J., Li, J., & Zhang, Y. (2019). SME-oriented flexible design approach for robotic manufacturing systems. *Journal of Manufacturing Systems*, 53(July), 62–74. <https://doi.org/10.1016/j.jmsy.2019.09.010>