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**ALIGNMENT OF A COLLABORATIVE RESISTANCE MODEL WITH A CHANGE
MANAGEMENT PROCESS IN INDUSTRY: A CASE STUDY ON PRODUCTION
AUTOMATION**

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ABSTRACT

Current research and literature lack the discussion of how production automation is introduced to existing lines from the perspective of change management. This paper presents a case study conducted to understand the change management process for a large-scale automation implementation in a manufacturing environment producing highly complex products. Through a series of fifteen semi-structured interviews of eight engineers from three functional backgrounds, a process model was created to understand how the company of study introduced a new automation system into their existing production line, while also noting obstacles identified in the process. This process model illustrates the duration, sequencing, teaming, and complexity of the project. This model is compared to other change process models found in literature to understand critical elements found within change management. The process that was revealed in the case study appeared to contain some elements of a design process as compared to traditional change management processes found in literature. Finally, a collaborative resistance model is applied to the process model to identify and estimate the resistance for each task in the process. Based on the objective analysis of the collaborative situations, the areas of highest resistance are identified. By comparing the resistance model to the interview data, the results show that the resistance model does identify the challenges found in interviews. This means that the resistance model has the potential to identify obstacles within the process and open the opportunity to mitigate those challenges before they are encountered within the process.

Keywords: *Automation, change management, collaboration resistance, case study, engineering change*

**1 MOTIVATION: HOW TO AUTOMATE
MANUFACTURING?**

As manufacturing companies seek to become more competitive in their markets by improving their processes, there has been a shift towards smart factories [1,2]. Smart factories are defined as manufacturing facilities that integrate technology within human-machine processes to increase reliability, agility, and productivity of the system. This adoption of more technology has made manufacturing innovation a greater focus in industry [1,3]. Research in academia has supported this technology introduction by developing frameworks around automation [1,3,4], Industry 4.0 [5-7], Operator 4.0 [8-10], the Industrial Internet of Things [5,7,11], Smart Factories [12-14], and Human-Cyber-Physical Systems [15-17]. Recognizing that while companies continually evolve as they become “smarter”, the manufacturers are introducing changes to the existing production systems [18]. Unfortunately, evidence suggests that approximately 70% of change initiatives fail [19,20]. Most research on engineering change has focused on product changes [21-26]. There appears to be little research focused on understanding the processes of introducing the desired manufacturing changes and how these are integrated into the broader system.

There is a gap within literature in understanding *how* industry introduces new automation systems. Efforts have been made in the past to characterize challenges in collaborative design, but not in the sphere of collaborative change management. For this reason, the use of exploratory research is beneficial. This paper will help bridge some of the gaps identified by conducting a case study to understand the change management process towards automation implementations in manufacturing.

The results of this study pertain to larger, multi-year automation projects. These projects will often consist of large cross-functional teams with high variance in team member representation, meaning people are not exclusively staffed on the project and different individuals might represent their team each week. The results from this study provide a case example towards understanding *how* automation can be implemented. Through this process, opportunities are identified that can enhance future implementation processes by minimizing the resistance within each task in the process. However, future work should validate the effects of applying the resistance model prior to implementations to verify this.

1.1 Overview of Change Management

This section provides a broad review of change management with models and processes focused on organizational changes, rather than engineering change management. Implementing a change requires a rigorous change management process for it to be fully accepted and to be successful [27]. Change management processes cover a range of elements to ensure a smooth transition and mitigate the amount of resistance. Resistance in collaborative activities is discussed in Section 3. Ideally during change management, significant evaluation is done for upstream and downstream processes to ensure no issues are introduced into the system [28]. Proper analysis helps prevent increased cost and delays within the schedule [28].

Table 1 briefly summarizes several change management processes found in the literature (rows) to key elements that make up effective change management (columns). While the principle goal of all the models is to aid in the process towards implementing a change, no method is the same. The final highlighted row illustrates the change process model extracted from this case study. This will be discussed in detail in Section 2.3.

Changes should only be initiated with clear, defined goals. In organizational change, this might include alignment of the change with the corporate vision. These goals drive the purpose of the change and serve as the justification for resource allocation. Beyond a clear set of goals, many models discuss the need to define a structured team that is empowered with implementing the change. This structured team is often drawn from multiple stakeholders to ensure that a broad, systems view of the change. This aligns with traditional engineering activities, such as design reviews and FMEA tools to enable collaborative decision making [29-34]. The third element focuses on ensuring that there is awareness of the change for all individuals directly and indirectly impacted. Transparency, as an organizational value, helps reinforce this element. As the change is being implemented, all stakeholders should be kept informed about the timeline, the impact, and any anticipated challenges. Finally, after the change has been implemented, a project brief, or post mortem, is recommended to review that the process was followed correctly, that the change was implemented well, and that any lessons learned can be transferred to future projects.

TABLE 1. CHANGE MODELS FROM LITERATURE

Change Models	Defined Goal	Structured Team	Awareness of Change	Project Debrief
McKinsey 7S [35-37]		Y		
Kotter's 8 Stage Process [37-39]	Y	Y	Y	
Kurt Lewin's Change [37,40-42]	Y		Y	
ADKAR [37,43]			Y	
Bridges Transition [44,45]			Y	Y
Nudge Theory [46-48]	Y		Y	Y
Engineering Change [26,49-52]	Y	Y		
High-Level Process Model	Y		Y	
Y = Yes, identified within the process				

The McKinsey 7S model consists of seven components: Strategy, Structure, System, Style, Staff, Shared Values, and Skills [35-37]. The model does not follow a sequential order, rather each component should be analyzed in parallel prior the change [35-37]. This model is presented a high-level management approach in considering the impact of a proposed change.

The Kotter's Eight Stage Process is configured as a step by step process for implementing a change [37-39]. The sequential eight steps are as follows:

1. Set the urgency,
2. Create a devoted team,
3. Formulate the goal and create plan,
4. Communicate goal and plan,
5. Empower individuals to act on the change,
6. Set short-term milestones,
7. Initiate more change, and
8. Make the changes concrete.

This model provides guidance on the overall process. Some of the steps require subjective considerations, such as setting the urgency. These subjective aspects of the model can be best addressed through collaborative decision making.

The Kurt Lewin's Change model is a simple three step process that is regarded as the foundation for many other change management models [37,40-42]. The process involves:

- Unfreeze (preparing for change),
- Change (executing the change),

- Re-Freeze (solidifying the change).

This model provides a general description of a state change model (before, during, after), without significant guidance on how each of these phases interact.

The ADKAR model has five elements that focus on how people acclimate to change [37]. The elements are Awareness (towards the change), Desire (to contribute to the change/empowerment of employees), Knowledge (of the change process), Ability (resources and skills available to implement in the change), and Reinforcement (method to enforce the change) [37,43]. This model is more focused on the culture of change rather than the implementation of change in a manufacturing environment.

Bridges transition focuses on the levels within change processes [44,45]. The transition comprises of three phases: “Endings” (leaving behind the old method), the “Neutral Zone” (establishing new processes, becoming more familiar with transition), and “New Beginnings” (culture shift to accept change) [44,45]. This model essentially uses the state change model of Lewin with the ADKAR model focused on culture adaption.

The Nudge Theory provides an opportunity for feedback throughout the change process [46-48]. The Nudge Theory defines parameters to the change, getting feedback from those impacted by the change, and presenting back the new change as the preferred ‘choice’ based on the feedback [46-48]. This feedback loop is central to monitoring the implementation of the change so that it does not have detrimental impacts on other aspects of the system. This approach is most similar to incremental continuous improvement as found in lean manufacturing principles [53].

Lastly, there is engineering change management, which focuses on design changes to a product or part [26,49-52]. This differs from the change management studied within this research, as the focus was on manufacturing processes relating to automation and not on the product.

Each change model has different key elements. However, some elements appear to be shared across multiple models. First, there has to be a clearly defined goal and plan [27]. Without this the project does not have a solid foundation when moving forward. Next it is important that there is a structured team preparing and implementing the change, with the addition of a designated leader [27]. Having a standard team, with little variation in representatives and team composition, will help increase the efficiency of the collaboration and communication [54]. Typically the most effective teams range in size from six to fifteen [55]. Alongside this it is critical that all individuals impacted by this implementation are made aware of the changes before the change process to implement the change [27]. This allows the individuals to be prepared and involved in the process, even though they may not be on the implementation team [27]. Lastly, upon completion of the implementation, it is helpful for

future implementation projects to evaluate the process used and identify opportunities [27].

Considering these models, it can be inferred that change management is a people-centric process. Not only does each step require input from people, but change impacts people [56]. Since change processes involve people, different levels of collaboration can be identified.

1.2 Overview of Collaborative Design

With this process involving high levels of collaboration, it is useful to understand collaboration as it relates to design. Throughout the change management process, communication is identified as a challenge, so applying a collaborative design model helped to understand some of elements in this process [55]. Collaborative design is where a team shares a common goal and together work by sharing knowledge and experience to complete tasks that lead to achieving the objective [55]. As compared to other design processes, such as concurrent engineering or set based design [57,58], collaborative design emphasizes the team having the same goal or objective [55]. The teams structure can be cross-functional, co-located or distributed, and can comprise of human or computer systems [55].

Within collaborative design, communication is critical but often poses as a challenge within teams [55]. To further understand where the challenges are occurring a collaborative design taxonomy was created [55]. The application of this taxonomy identifies the elements of collaborative design that introduces resistance [55,59].

Many engineering design processes follow a generic process that starts with defining a problem, generating concepts, detailing these concepts into solutions, and validating these against the initial problem [60-63]. These processes are typically executed in collaborative teams to manage the complexity of the problem, process, and product [29,64,65]. Further, it has been observed that engineering design is a complex social activity [66,67]. The design process, at a high level, is similar to the general steps of the change management models.

2 CASE STUDY OVERVIEW

To execute this exploratory research and gather a better understanding of the change management process for automation implementations, a case study research method was used. With the context of this research focusing on *how* and *why*, this was the most suitable method, since case studies are useful for studying phenomena in their contemporary context [68,69]. For the overall case study, semi-structured interviews were used, which is a branch of qualitative research [68,70].

2.1 Pilot Study: Defining the Questions

To gather the desired information in the case study, the right questions needed to be asked during the interviews. For this reason, a pilot case study was conducted. Throughout the

duration of four months in the “Research Methods in Collaborative Design” course, five graduate level mechanical engineering students participated in gathering data for the pilot study conducted at several manufacturing companies across different industry sectors. These companies were near the university, which allowed the students to tour and become familiar with the manufacturing processes, as well as interview the employees in person. The companies were all medium sized enterprises (5,000+ employees).

The questions used for the pilot study were divided into three categories: current process, change management process, and post-implementation. Conducting this pilot study helped filter the questions and refine the final set of questions used for the main case study. For example, in the pilot study, the interview started by immediately asking about the current process, so no information was ever gathered on the individual’s role in the organization or involvement with the automation. The individual’s role would be important in order to further understand the collaboration element to this process. Therefore, the first set of questions were changed to focus on background information such as asking the interviewees role in the organization, understanding their daily responsibilities, how they were involved with the automation, and how the automated system compared to others they might have worked with. By understanding the interviewees role, more context was provided towards their view on the automation, as well as their part in the process. The case study interview questions were then reframed to cover background information, the change management process, and the post-implementation.

2.2 Case Study Company Background

This case study was conducted at a large manufacturing firm with (10,000+ employees). This was a low volume (couple a month), high complexity production facility (millions of components). All the products were customized and made to order. Due to the product, the manufacturing processes consisted of many manual tasks, which resulted in a lower throughput. However, with the advantages of automation, there has been a shift towards adoption of these advanced technologies in hopes to increase the speed of production and improving quality and reliability.

At this firm, the implemented change studied was related to the manufacturing process and not the product itself. This automation example was a collaborative effort between human and machine to complete a task. In this example, the automation implemented was reducing the level of automation by incorporating more human activity. The context of this study was centered on evaluating the process of an already implemented automated machine for several years prior. This was an ideal example to study as some of those involved in the implementation were available to speak with to better understand what occurred throughout the process.

This study was conducted within a half a year span. Interviews were conducted with representatives from three core

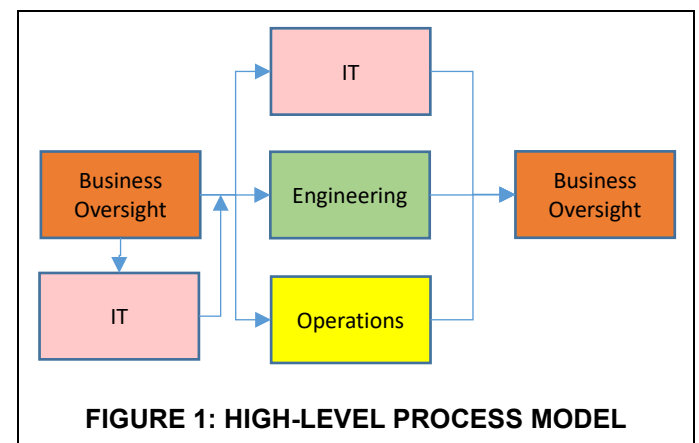
teams: engineering, IT, and operations. Due to the nature of proprietary information, these interviews could not be recorded, and further company details will not be disclosed. Since the interviews could not be recorded, data was collected through notes and follow-up interviews were conducted to verify and validate the information. Interview recap information can be found in Table 2.

Table 2. CASE STUDY INTERVIEW OVERVIEW

Name	Function	Duration (min)	Location	Week
Isabella	IT	60	G	2
		50	C	3
		45	V	23
Emma	Eng.	35	V	4
Ivy	IT	60	G	2
		35	C	4
		45	V	26
Olivia	Ops	40	C	7
Opal	Ops	30	V	8
Ingrid	IT	60	G	11
		60	C	10
		60	C	10
		50	V	21
Ellie	Eng.	45	S	6
Irene	IT	90	C	3
Location: G = Gemba Walk, C= Conference Room, V = Virtual by phone/WebEx, S = Shop Floor				

2.3 Process Model

Upon gathering the interview data, a process model was created to help understand the different roles’ contributions to the implementation. It also helped identify the collaboration between the different functions throughout the implementation. This process model was then validated through follow up interviews. This high-level process model can be viewed in Figure 1.



Within the high-level process model, the different roles were represented by different colors (IT: pink, Engineering: Green, Operations: Yellow, Business Oversight: Orange). This helped

identify where in the process different teams were brought in. It also shows how the teams were collaborating with one another throughout the process.

The process starts with the business team which evaluates the current state operations. Upon identifying opportunity areas, projects can be developed and proposed to leadership. If there is buy in, a project team will be created and the respective tasks funnel into the different functions. The project then comes back together sustaining and supporting the machine in production. The significance of this model is that it starts with one team or representatives and expands as the project develops, however, it comes back together at the close of the project.

Analyzing the process identified, the execution of many tasks was completed with minimal collaboration with members outside of their function. This is referred to as the ‘Silo Effect’ [71]. This is not to say that the teams did not communicate amongst one another, more so they communicated and collaborated within their team before reaching out cross-functionally.

Comparing the high-level process model seen in Figure 1 to the Lewin’s Change Management Model in Table 1, there are several similarities. The beginning of the project focused on collecting the right information and forming the right team for the project based on the defined objective. This is like the unfreezing stage of the Lewin’s Change Management Model as it’s preparation for the change [37]. As the high-level process model in Figure 1 expands to the different functions, this is the stage in the process where teams are taking action to complete their tasks. This is essentially the ‘Change’ phase within Lewin’s Change Management Model as the process transitions [37]. The last phase of the high-level process model is where the actions come together to sustain and support the implemented automation. This is similar to the refreezing stage of the Lewin’s Change Management Model as the change is solidified and accepted [37]. From the high-level process model, the unfreezing and refreezing in the process are done by one

functional team, while the change phase is executed by many functional teams.

Evaluating the high-level process model, the key change elements can be found in the last row of Table 1, highlighted. From the interviews, it was observed that the project did start with a defined goal of what the company wanted to achieve with the automation implementation. Additionally, an initiative was made throughout the company in efforts to make everyone aware of the change. While there was a team involved in leading the change, representatives for the team were constantly rotating, for this reason this process was considered to not have a structured team. Also, there was no project debrief identified throughout the study. This was an opportunity identified for future implementations.

3 CREATING A COLLABORATIVE RESISTANCE MODEL

With any kind of change, some level of resistance is introduced [72]. Identifying the resistances within a process can help mitigate them in the future [73]. To better understand resistances within design changes, a collaborative design taxonomy is used as a framework to apply resistance values to a design process [59,74]. Once the step by step process has been identified, then each task in the process is rated on a scale (high, medium, low) for each of the taxonomy levels [59]. The resistance per task is then calculated using Equation 1. Total Resistance Per Collaborative Scenario [21]. Evaluating the resistance totals for each collaborative task shows which task has the highest or lowest resistance [59].

$$R_{\text{task}} = \left[\sum_{i=1}^N \frac{1}{R_i} \right]^{-1}$$

Equation 1. Total Resistance Per Collaborative Scenario [59]

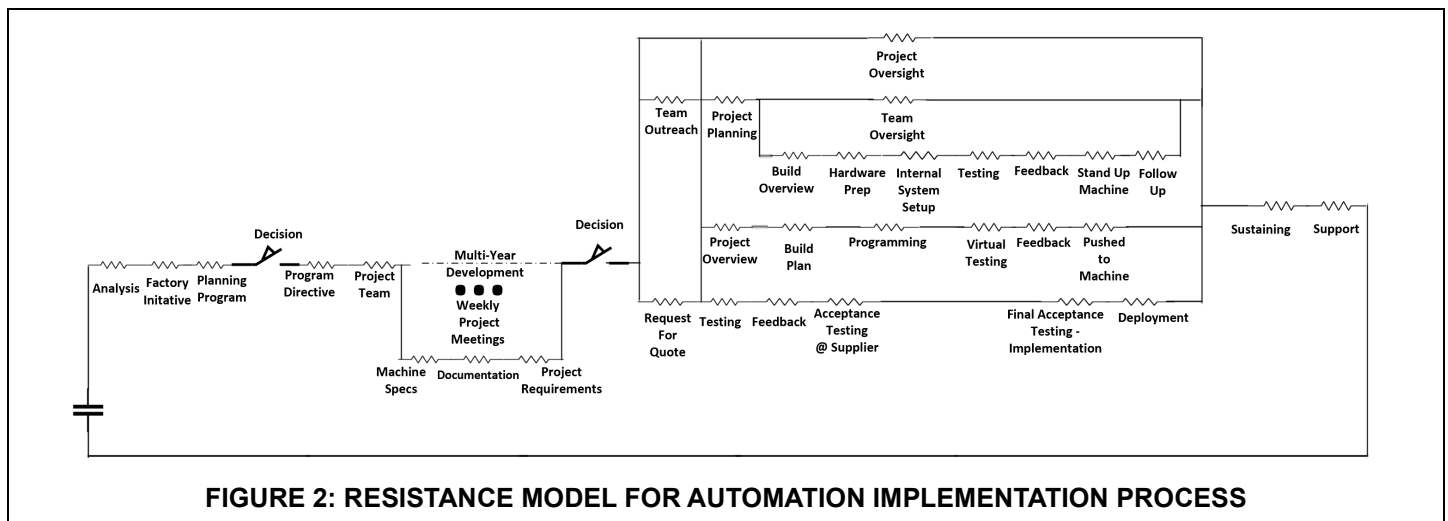


FIGURE 2: RESISTANCE MODEL FOR AUTOMATION IMPLEMENTATION PROCESS

Since the collaborative design model was designed specifically for design scenarios, there were limitations to applying it directly to this example [59]. The process that was identified through the case study was a combination of a change management process and design process. Therefore, evaluating the resistances of the change management tasks with a collaborative design taxon does not provide a direct application. For this reason, not all the taxa covered in previous work are used [59,74].

3.1 Proposed Resistance Model

From the process model, a resistance model was created based on the criteria for parallel or series resistors [59]. Figure 2 shows the developed resistance model for the automation implementation. Each task within the model is scored on a scale of high, medium, or low resistance for each of the taxa that are applicable to the project. The taxa that were applicable to this study were group size and culture, problem abstraction and complexity, information form (design artifact or background), information ownership, dependability (completeness), and mode of communication (verbal/written) [55,59]. These taxa are tabulated by category in Table 4.

Taxa such as type of problem (novel), scope (high), communication language (English), evaluation of design approach progress (assessed by leadership) are all taxa that did not change throughout the process, so they were not evaluated for resistance. In addition to these, the taxa for distribution of people and information were also not evaluated, because they both were widespread geographically and organizationally for all tasks, leading to the same resistance for all tasks. There were frequent rotations in the project team with new members being added and others being dropped at all stages of the project. This is because few people were staffed on the project as their full responsibility. For this reason, the availability taxon was also removed from the resistance scoring. As will be discussed later, this team rotation leads to a higher resistance as a result of the continual changes within team representation.

3.2 Example of Resistance Scoring

The resistance scoring was done for all the tasks identified in the process model, totaling 34 tasks. An example for how the tasks were rated for resistance can be seen in Table 4. The three collaborative activities provided as examples are the pre-change analysis, the planning program, and the weekly all-team project meetings. The pre-change analysis is where the current business process was evaluated, which primarily consisted of business support individuals. The planning program is the proposal for the project, such as calculating return on investment. This usually involved business support and leadership. Lastly, the weekly all-team project meeting were status updates throughout the duration of the project, involving a representative from all core teams on the project. This resulted in a large cross-functional rotating team. Additionally, the collaborative activities were evaluated on a geometric scale of 1, 3, and 9 for low, medium, high respectively. This helped show a larger distribution between the resistances.

Table 3. EXAMPLES OF RESISTANCE SCORING

			Factory Analysis	Project Planning Phase	Weekly All-Team Project Meeting
Team Composition	Group	Size	Low (1)	Med. (3)	High (9)
		Culture	Low (1)	Low (1)	High (9)
	Abstraction		Low (1)	High (9)	Med. (3)
	Complexity		Low (1)	Med. (3)	High (9)
Information	Form (Design artifact or background)		Low (1)	Low (1)	Med. (3)
	Ownership		Low (1)	Med. (3)	High (9)
	Completeness		Med. (3)	High (9)	High (9)
Communication	Mode		Low (1)	Med.(3)	High (9)
Total:			Low	Medium	High
R _{task}			0.12	0.257	0.629

The resistance values applied were based on the objective characteristics from the case study interviews and scored based on evidence in literature on the characteristics' impact on collaboration. Reviewing each of the resistance values that were applied, the pre-change analysis consisted of a small team size (less than 5 individuals), therefore it was labeled with a low resistance. The project planning phase consisted of a medium team size (between 5 and 10), so it was given a medium resistance rating. However, the weekly all-team project meetings were given a high resistance rating, because the size of the team was large (greater than 10).

Next the evaluation of culture is considered, which was viewed as the organizational/departmental culture. While there are many advantages to cross-functional teams [75], there are also associated challenges. From literature, functional characteristics, such as language, such as team specific acronyms, and diverse team responsibilities can create a hurdle for effective collaboration [76]. So, following the composition of the teams, since both the factory analysis and the planning program consisted of mostly members from the same department, they were labeled with a low resistance. While the weekly all-team project meeting consisted of over seven different departments, their culture was labeled with high resistance due to their variety and diversity [77].

The next evaluation was for the abstraction of the problem. As previously stated, the pre-change analysis was a routine analysis of the factory process, meaning it was a more concrete process, deeming it a low resistance [74]. The planning program was the development and refinement of the project. Since this was an opened-ended step, a design team could have aided this task. However, this was a team consisting of individuals within the same department proposing a plan to leadership. This plan consisted of a broad project idea, return on investment, and resources needed. As this information was high level (abstract), the collaborative activity is scored with a high resistance [74].

Throughout this defining stage, the planning program could have benefited from a diverse team to help work through some of the ambiguity within this task. With the weekly all-team project meeting while there was a problem statement, there were many elements that required clarification, but since there was more context to the tasks, the level of abstraction was considered intermediate. Additionally, since this was a cross-functional 'design team', the resistance was lower than the planning program. For this reason it was evaluated as medium resistance [74].

Next, complexity was evaluated based on its definition looking at the degree of overlapping components and difficulty to complete the task [78–81]. The factory analysis was reviewing the production data and processes. This was done routinely to ensure timely throughput, so the complexity was low leading to a low resistance. For the project planning phase, there were several components that affected the outcome of this task, but it also could be completed with less difficulty by having the right information. For this reason, the resistance was considered medium. Finally, due to the many overlapping components in the weekly project meetings and the challenges faced with the larger team this led to a high complexity, which resulted in a high resistance.

The next element evaluated was the information, specifically the design artifact [59]. The design artifacts are the information and data that provide context to the project or task [55]. The resistance scoring was based on the presence of design artifacts, the less information the higher the resistance [82,83]. Since the factory analysis was all based on manufacturing data, this stage curated many artifacts, this resulted in a low resistance. Since the planning program required presenting the design artifacts to leadership for approval, such as defining the context of the project and the return on investment, this resulted in a low resistance. As the project picked up speed, the weekly all-team project meetings generated project updates and defined requirements. However, the resistance here was the lack of thorough tracking of these artifacts, resulting in medium resistance. A high resistance rating would be if there were no design artifacts or context to the given task.

Next, the ownership of the information is considered. Within this project, as more teams became engaged, the more distributed the ownership was on being able to make changes to the information. This relates closely to change management [74], because if someone made a change and any questions arose, then proper documentation would provide with who made the change so they can be contacted. Additionally, with more individuals capable of making changes to the information there is less sense of ownership which can cause resistance if individuals are not making the proper updates as a result of relying on someone else to make the appropriate changes [74]. For the pre-change analysis, since there was only one team involved, few were able to make official changes to documentation which is why the resistance rating was low. For the planning program, since there were several teams involved

this increases the ownership of the information, which is why the resistance is medium. Similarly, since the weekly all-team project meetings involved all the core teams (>7 teams), the ownership of the information was widespread, which led to a high resistance rating.

The next resistance evaluated for information was for the dependability and completeness. Completeness evaluates the task based on the amount of changes that will be made to the information after the task is completed [84]. While the pre-change analysis evaluated the production process, changes were always being made to the process which meant the information was changing, this resulted in a medium resistance. Due to the high level of uncertainty and context of the planning program with defining the project, many variables needed to be defined later in the project. For this reason, the resistance was considered high [83]. The reason the weekly all-team project meeting was also rated a high resistance was because it was the responsibility for each team to update and add their information to the shared database. However, the information stopped being updated causing incomplete information. Incomplete information causes resistance and can introduce issues later on in the process [85].

The last element evaluated was communication used during and between each collaborative activity. The modes of communication identified for this project were both verbal and virtual (written). Further influencing the challenges, or resistances that arise from communication within the teams, is the number of people involved in the information sharing and their understanding of whether the information they hold is unique. Thus, shared information sharing based on team familiarity during collaborative design reviews is used as a means to score this resistance [30,31]. Applying this, the factory analysis had a lower resistance, the planning program had a medium resistance, and the weekly project meetings had a high resistance.

It should be noted that these resistances are treated as independent in this modeling approach. The original and redefined collaborative design taxonomies both recognize that there are interdependence between the taxa [55,86]. This interdependence is reserved for future study and investigation.

4 RESULTING OPPORTUNITIES

Comparing the interview data with the resistance model confirmed that the resistance model acceptably identifies the challenges highlighted in the interviews. This suggests that the subjective obstacles discovered in the interviews aligned with the resistances found for the resistance model based on the objective characteristics from the interviews. This means that the resistance model predicted the areas of highest resistance. By knowing the highest resistance tasks, action can be taken to help mitigate or reduce that resistance to change [73].

Through this analysis, opportunities for improvement are identified. As shown in the high-level implementation process model in Figure 1, the teams operated in a siloed fashion. An opportunity identified is for increased collaboration with

members outside of individual functions. With an increase in cross-functional teaming, projects are at an increased rate to achieve success [87]. This will also naturally increase the collaboration between members of different teams leading to an increase in team familiarity, which leads to more effective collaboration [54].

Another opportunity identified is to incorporate the operators of the automation equipment earlier in the implementation. While a new machine is being designed, it is critical for the operators to provide input on what might be needed, such as information they need to see on dashboards. This aligns with general design principles, such as user-centered design where the users are the operators [88,89]. Instead of waiting to gather input from the operators after the machine has been stood up in the factory, the operators can provide perspective into key elements during the development phase which can increase the efficiency of the process. This introduces the topic of socio-cyber-physical systems, where the automation that is implemented is to support the human rather than the human supporting the robot [9]. Balancing this relationship between human and automation will affect the operator's situational awareness during that task [9].

Reviewing Table 4, the pre-change analysis had the lowest resistance and the weekly all-team project meeting had the highest resistance for all the tasks evaluated. Since the pre-change analysis consisted of few changes, the resistance evaluated was low. On the contrary, the weekly all-team project meeting consisted of a high change, which led to the evaluated high resistance. It should also be noted that collaboration was different when comparing the pre-change analysis and the weekly all-team project meetings. The weekly all-team project meeting certainly required more collaboration as the team size was much larger, but it had the highest resistance, as compared to the pre-change analysis which encountered less collaboration and had a lower resistance.

As was previously stated, the frequent change in departmental representation at the weekly meetings resulted in high resistance. This change resulted in large, dynamic teams, confusion on whom to communicate with (as a point of contact), and siloed teaming and more. While it might not be cost effective to have a team such as this dedicated full time on a multi-year project, having more consistent representation through a smaller rotation pool might increase the collaboration and effectiveness of the team.

Additionally, documentation was not thoroughly kept track of throughout the project. This could be for a variety of reasons, one being if they had a set structure of what information needed be provided or not, then it could be that the teams just did not know what information to share. From this it is suggested to have a more defined documentation process. Through documenting the information and collecting the data throughout the process can help develop a digital twin for future implementations [17].

Lastly, more controlled ownership and defined responsibilities may help structure the larger teams. This will remove any confusion as to what the roles are and ensure that individuals are completing the required tasks. For example, delegating the representative at each weekly meeting to update their departments information on a database will ensure that the information is up to date for others to access.

5 CONCLUSION AND FUTURE WORK

In conclusion, this case study followed a change management process for an automation implementation. When building this process model and comparing it to other change management process models found in literature, several similarities emerge. From having a defined project objective, gathering the right resources, and forming the right project team all contribute to an effective change management process.

Additionally, the results of this study highlight the potential to use the resistance model to predict obstacles within a change process before they occur. This opens the opportunity to mitigate these obstacles. The benefit of this could potentially increase the efficiency of the implementation, which could lead to cost savings later in the process. There is also reason to believe that similar resistances would be found if other change management processes were used.

From this process it also became apparent that the change management model identified contained elements that emulated the design process. While the design process and change management process are similar, they are not the same. For this reason, the use of a design taxon could not be directly applied to aspects of the process that related to change management. However, this highlights an opportunity for future work to investigate a new taxon that perhaps relates to collaborative change management.

Additionally, while this study was conducted at a large, organizationally diverse company it would be beneficial to see how these results might be different at small-medium enterprises. Future work can therefore look at the applicability and compare the differences to small, medium, and large enterprises.

In addition to all of this, studying the applied effects of using the resistance model prior to an implementation to see whether some of the challenges were effectively mitigated would benefit this research. If the model was successful in mitigating the challenges, the benefits to this would be impactful for future automation implementations.

Finally, the resistance model was the only aspect studied of the electric analogy [59]. Two other aspects need to be explored further to be able to complete the electric analogue model. These include developing the models of current (active knowledge) and voltage (passive knowledge). Active knowledge includes the information that defines the problem and product [78], including models such as requirements, function models, solid models, and analysis models [90]. Each representation will provide different

value to the engineers in answering questions. This value of representation is currently under investigation [91–93]. The passive knowledge would be the background knowledge or understanding that is available to the engineering team. This would include knowledge found in engineering curricula, gained through experience, or encoded in textbooks or other documentation. These aspects need to be studied further.

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