DEVELOPING A PROTOTYPE PROCESS: ENHANCING COORDINATION AND PLANNING IN PROTOTYPE MANUFACTURING

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ABSTRACT

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Developing a Prototype Process: Enhancing Coordination and Planning in Prototype Manufacturing

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Certain infrastructures are important if not necessary in the process of producing prototypes and pilot products. The current process at COMPANY A is unorganized and works through informal practices. The process utilizes a proto team that has ties in both the R&D and production teams. The aim of this thesis is to analyze the issues within the current process, and through comparing it to similar well-working ones, create a new and improved framework for the company to utilize.

The current operational system has some bottlenecks that are identified; scheduling as well as material acquisition are recognized as the biggest issues. The findings for solutions are varied, but many emphasize communication and the knowledge of everyone involved in the process. These prove important due to the interdisciplinary nature of the process, as well as how informal the process has been in the past.

The results show the possible improvements divided into realistic and idealistic solutions based on how much effort and resources they would take to implement. The realistic solutions include things such as creating a new MIS -system for the process and advancing material acquisition. The idealistic solutions include seamless communications.

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Prototyyppiprosessin kehittäminen: Koordinoinnin ja suunnittelun parantaminen prototyyppien valmistuksessa

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Tietyt infrastruktuurit ovat tärkeitä, elleivät välttämättömiä, prototyyppien ja pilottituotteiden tuotantoprosessissa. COMPANY A:n nykyinen prosessi on epäorganisoitu ja toimii epämuodollisten käytäntöjen kautta. Prosessissa käytetään prototiimiä, joka koostuu sekä tutkimus- ja kehitys-, että tuotantotiimien jäsenistä. Tämän kandidaatintyön tavoitteena on analysoida nykyisen prosessin ongelmia ja vertailla sitä vastaaviin hyvin toimiviin prosesseihin, ja sitä kautta luoda uusi ja paranneltu viitekehys yrityksen käyttöön.

Nykyisessä toimintajärjestelmässä on joitakin tunnistettuja pullonkauloja; aikataulutus, sekä materiaalien hankinta tunnistetaan suurimmiksi ongelmiksi. Löydetyt ratkaisut vaihtelevat, mutta monet korostavat viestintää ja kaikkien prosessiin osallistuvien tietämystä. Nämä osoittautuvat tärkeiksi prosessin monitieteisen luonteen sekä aiemman epämuodollisuuden vuoksi.

Tulokset esittelevät mahdolliset parannukset jaettuna realistisiin ja idealistisiin ratkaisuihin sen perusteella, kuinka paljon vaivaa ja resursseja niiden toteuttaminen vaatisi. Realistisiin ratkaisuihin kuuluvat esimerkiksi uuden MIS-järjestelmän luominen prosessille ja materiaalien hankinnan edistäminen. Idealistisiin ratkaisuihin kuuluu saumaton viestintä.

SYMBOLS AND ABBREVIATIONS

Abbreviations

AC	Alternating Current
BOM	Bill of Materials
DC	Direct Current
MIS	Management Information System
R&D	Research and Development

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The author, Iisa Vaara, takes full responsibility for the content of this thesis and has reviewed and edited the content generated by the possible use of AI tools.

1. Introduction

A collaborative ecosystem is essential within the countless manufacturing processes happening in the world. This sort of ecosystem facilitates the sharing of ideas and speeds up the assimilation of new technologies, increasing product quality, production, and profitability. One area where collaboration is especially paramount is in the production of prototypes and pilot devices. At present, COMPANY A's multidrive production line incorporates the leaders of the production line into a dedicated prototyping team responsible for supporting product development through the construction of prototypes of new products and product revisions. However, this proto team relies on an informal way of cooperation with the research and development (R&D) branch of product development instead of having a well established procedure themselves. This sort of unstructured process is more likely to result in inefficiencies, poor resource management, and challenges with planning.

The current operational structure for multidrive prototyping at COMPANY A follows an unstructured and more colloquial approach to product development and production collaboration that compromises the capacity to foresee demands and efficiently manage resources. In such an environment, the decisions tend to be made reactively instead of proactively, which also leads both teams to struggle with transparency in their roles, responsibilities, and expectations. Determining a precise and uniform procedure that promotes smooth cooperation and allows for improved planning of both operational and resource requirements is crucial to overcoming these obstacles.

In the technology industry 'closure', such as the act of completing operations in a process, usually implies the total dissipation of the problems (Pinch et al., 1984). This can even act as an obstacle for starting to create something new due to anticipation of failure or the possibility of misusing resources. Despite this, an important factor of a firm's skills is the ability to manufacture efficiently (Mukherjee et al., 2000).

An array of methods and tools are essential in supporting the development of constructing physical prototypes, increasing efficiency and the effectiveness of the production line (Schork et al., 2018). Therefore, this paper delves into a new approach to prototype development through a method of defining the necessary requirements for a well-working prototype process, maximising knowledge gathering in a timely and comprehensive manner.

This will focus on creating an organized framework that will guide the interaction between the prototyping team and the product.

1.1. Defining prototyping

Prototyping is defined as “an initial instantiation of a concept as part of the product development process” (Christie et al., 2012, 2), or “Based on the Greek terms “protos” (*the first*) and “typos” *(kind of*), the term “prototype” stands for *the first of its kind*” (Schork et al., 2018, 5). Engineers utilize prototyping to receive information about manufacturing and assembly, to investigate possible issues with system integration, and advance analysis. Prototyping can even be used in the designing phase of a project to benefit designers with setting boundaries for their considered concepts. (Christie et al., 2012). Prototyping is undoubtedly a significant component in the process of manufacturing. It can even be seen as the core of the whole process of innovation.

Creating a prototype acts as an important step in creating a product. The idea of a product may vary, and thus creating a physical model is crucial in the solidifying of ideas and concepts. As prototyping acts as a sort of draft of a product, the idea is most often to eventually create a streamlined production of the product once it is refined and bettered. A physical prototype may also be subjected to tests better than any simulation could, furthering the research and development of the product. These tests then conclude in revisions based on the results and feedback from the process.

1.2. Research questions

The main research problem of this paper is how COMPANY A’s prototyping process can be developed. It will mainly focus on the ‘Drives’ -department, and the way that they handle their process currently.

This paper will identify the problems in the current prototyping process, as well as consider practices utilized in similar well-working processes to then create a structure for a new and improved version of the current process at COMPANY A.

The most significant limitation of this thesis is the lack of interviews. The description of the current process in this paper is based on an informal conversation had inperson, as it helps keep the anonymity up as well as uses up less time and resources from everyone involved.

2. Methods

The contents of this thesis are mainly made up of a literature review. It is important to understand the relevance of the surrounding research as well as how it affects the research being done. With the main objective of this thesis being creating a new and streamlined version of the current prototyping process, the makings of a well-functioning process are essential to grasp. This was decided to be the most straightforward and smooth way to realize the system of researching.

Starting research with finding what other people have already explored or investigated gives us access to a wider scope of ideas, as well as more specific information to collect ourselves, and leaving us with a more minute burden of sifting through further research (Gough et al. 2017).

One visit was done to the COMPANY A offices and factory in February. The information obtained about the workings of the current prototype process were discussed on this trip and are based on verbal descriptions of the process, including its downfalls and bottlenecks. There was a small tour done of the lots currently in use for the prototyping team, as well as a portrayal shown of the software used by both development teams to schedule upcoming projects.

This sort of informal interview was conducted due to the restraints on time and resources. It also proved to be a convenient method for everyone involved. The data gathered from the visit was written down and subsequently used in the analysis to further the researching process. The privacy of the sources and possible sensitive data has been redacted due to the company's policies.

3. Results

This section will delve into the current prototyping system being operated at COMPANY A and examine the bottlenecks expressed by the people working on it. Then the ideal situation will be presented, based on similar comments from employees. The importance of a well-working prototyping system will be discussed and examined and used as an incipience for further discussion.

3.1. Electric drives

A simple drive is made up of a prime mover, transmission, and mechanical working load. In contrast, an electrical drive is an electromechanical device that uses the aforementioned parts to transform electrical energy into mechanical energy to provide motion to various machines and mechanisms for various types of process control.

Many modern industrial uses of electricity require some sort of drive motor for the appliances and tools used for the application. Automation developments and the global transition to more energy-efficient and sustainable technologies are linked to their increasing influence in the field.

COMPANY A currently manufactures electric drives, ranging from low and medium alternating current (AC) drives to direct current (DC) drives and power controllers. The applications of these drives can stretch from industrial cranes and injection moulding machines, all the way to household objects such as fans and food mixers. Cabinets with different voltages work differently, even though their functions are very similar. COMPANY A's assorted variable speed drives are currently being sold to numerous countries around the globe.

3.2. The current prototyping process

The current process for prototyping multidrives at COMPANY A is mainly commandeered by the research and development (R&D) team. The beginning of the process starts from the

end of the process. This consists of reserving a time for various tests to be done for the prototype at the end of its lifecycle. This immediately sets a timeframe for the entire process simply from the first decision made. The required tests include vibration, short circuiting, heat and seals/IP ratings. These are the tests required for analyses that have been established as valuable for the process as well as the customer's needs.

The planning of the cabinet drive is then executed by the R&D team to fit the needs of the client as well as fulfilling the requirements for these tests. These plans are then sent to the production line, and the prototyping team orders the needed materials. The line only has access to the materials that already exist, and thus if there are any specialized materials the production line needs to scrutinize and resolve these issues on their own. This causes significant delays in the process.

The production line gets the bill of materials (BOM) of the planned cabinet only once the designing is done by the R&D team. This is also something that slows down the planning of the production angle of the project.

Once the genuine project can be initiated, the materials should be allocated to their proper places, also known as where and when they will be needed down the production line. All of the materials do not fit in the lots reserved for prototyping, and they should not all arrive at the same location at the same time.

The confirmations of work and time used on the project need to be done individually and by hand by the project manager of the specific project, because the current programme in use, a management information system (MIS), does not recognize the prototyping projects due to their divergence from the usual production line. The prototypes lack a sales number which is utilized in conventional customer deliveries. After the cabinet has been built, it can be sent off for testing to the testing site. The confirmation of hours of work done needs to be done again from the office by hand to signify that the cabinet is finished.

The timing of the process can vary, and needs to be scheduled well due to the lack of lots reserved for prototyping projects. The time the project needs is built of a few different blocks; this namely includes the planning, creating a BOM and drawings, and the actual building of the prototype. Cabinets that are very standard with only a few modifications can take as little as 3 weeks, whereas a bigger cabinet that requires more attention may take up to 12 weeks. Complexity immediately adds more time to a project, since creating and

planning new materials and parts takes up more time than a project where ready materials can be used.

Taking everything into account, the lifecycle of a prototype in this current process is as follows: being planned, getting built, getting tested, and finally, getting destroyed and recycled. This is what a considerably typical prototyping process looks like from a firm's point of view.

A large number of problems still exist within the process due to the lack of a specific and streamlined formula to be used. The main issues can be divided into two overarching sections. These include the procurement of materials as well as the BOM, and scheduling. These will be used in the analysis as the foundation for the building of a new prototyping process. Subsequently the bottlenecks of the current process will be examined.

3.2.1. Acquisition of materials

A remarkable number of delays in the production line for prototyping come from how long it takes to acquire the needed materials. This is especially true in cases with a greatly modified cabinet that requires a great deal of parts that are not easily and readily available. A positive efficiency for some materials is that they can be modified at the production line itself. For example, a beam that is too long can be sawed to its desired length and fit into the build that way instead of having to wait for the readily modified part.

A solution for this would be to get the BOM to the production line as early as possible, enabling the ordering of these unique materials to be done on time, or at least with respect to the possibility of it taking weeks to procure them. This would stop the stilling of the production line due to materials being on their way or unavailable for a time.

3.2.2. Scheduling

The second aforementioned major problem arising in the production line for prototyping is scheduling, whether it be for the lack of time or constant traffic within the process. There are specific lots in the factory reserved for use for the prototyping projects, but these are few, and thus if a new project needs to be started on the same lot, it may very well be delayed.

Occasionally there will be requests for projects at the same time, and this results in further setbacks.

Another reason jams may occur related to scheduling is that the first action done in the process is setting the date and time for the testing of the prototype. This creates a preliminary schedule for the whole prototyping process, but when a delay occurs, it can then off-set the entire production plan.

3.3. Ideal situation

The ideal situation describes what the optimal way of working would be for the multidrive prototyping process. These will be described in a perfect way in a vacuum, which means some may be unattainable or more unrealistic than others. Later on, these options will be considered within the confines of COMPANY A's current system, and discussed how it could be modified to contain these while not to uprooting the entire process.

In a perfected situation, getting information on specifics of what needs to be done and when would already prove as a massive reform for the process. This would only require more work from the product development team by informing the production line of their planned projects and what to expect. This exists in a perfunctory way with the current version, which utilizes having an excel sheet and calendar to track progress along with important deadlines. In an idealized world, the communications would be seamless and almost mindlessly easy from each participant to the next engaged in the process.

When the production line gets information of the planned projects, they should already be planned far ahead. This contradicts the point made above, but just means that once the employees on the production line receive the information, the project should be designed clearly and the project manager should have had access to order materials and plan the production.

The BOM should be readily available, and everything that needed to be ordered could be done so for. In an ideal world, the materials would be accounted for and allocated by the morning of the day the contruction would be ready to commence. This would also require one of the lots meant for prototyping to be free and ready to be utilized in an opportune way.

The most complicated parts to obtain should be the ones that commence first. They would then be available for the production line without the need for a convoluted process just for the obtainment of the needed materials.

Another improvement for the production would be getting a working management informtaion system (MIS) just for prototyping. Currently, the system being used in the regular production line does not work for the prototyping process due to the proto process not following as streamlined a process as regular orders. They do not have a 'production order' number like all the others, and thus the software does not recognize the projects. A perfectly working process would require a well-functioning version of a MIS, which would ease the flow of information between different departments involved.

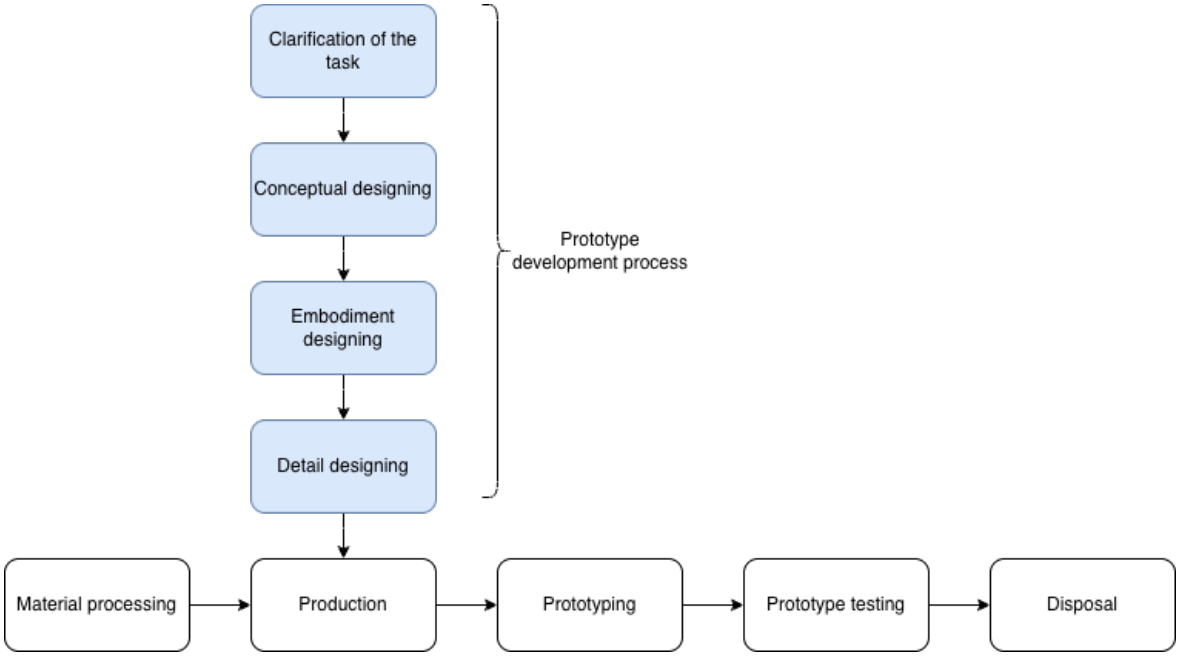

Figure 1: A holistic prototype and process development model (based on (Birkhofer et al. 2007) and (Schork et al. 2018))

3.4. Well-working prototype systems

Diversification in technologies is very much a social process (Bijker, 1995). The improved prototyping process needs to be a clear system outlined for everyone invovled in it. On the other hand, a good project works through trial and error. People are hesitant to try anything new due to the comfort of familiarity, even though that is where innovation thrives. "The

easiest way is not found by calculation, for calculation does not come easily." (Pirie, 2015, p.168).

A well-performing and balanced production line can be viewed in many ways, but Mukherjee et al. (1990, 142) states as follows: "The general description of routine performance of a production line in equilibrium contains two elements. First, the line must retain in its repertoire all routines the line invokes in the given state of operation. Second, the operators of the line must be able to receive, interpret, and respond to messages by executing appropriate routines at appropriate times."

Designers must cooperate with the prototype in an intimate way (Buccarelli, 1994). This entails knowing the ins and outs of what is being designed. When there are many people working on the same process, this is what can easily create confusion when not communicated properly.

Prototyping as a concept is used very loosely in literature, resulting in unspecified and much too varied a pool of sources to gather distinct information from. On the other hand, prototyping as a process is based strongly on personal trial-and-error as well as the knowledge of the project manager (Schork et al., 2018).

Yu et al. (2018) recognized that despite their differing titles, the execution of designers and engineers became less discrepant throughout the process of designing and prototyping. The development of new technologies, tools and materials is contributing to the diminishing of the confines between the different disciplines.

The "absorptive capacity" of a firm illustrates the process of learning and implementing new practices into a production line. Many firms, while focusing on their main manufacturing then lack the absorptive capacity for adapting adequately to requirements that may not be within the scope of their intial manufacturing (Mukherjee et al., 2000). This means that some production lines have a harder time switching over from one task to another, viewing them as tasks to complete instead of trying to be as efficient and favorable as possible. This changing over from one task to another perfectky would thus require unlearning and re-learning of a new skill or habit which often proves difficult and relies on a company's financial and intellectual assets.

A well-working prototyping process relies on individual, social, and organizational structures. These are illustrated in the table below with the concerns linked to each perpective presented.

Table 1: Behavioural Perspectives in Prototyping Processes (Cooprider et al., 1990)

Perspective	**Concerns**
Individual	Talents and skills
	Experience
Social	*Intra-team communications*
	User-builder environment
	Design convergence
	Project Management
	Extra-team communications
	Boundary management
	Innovations
Organizational	Coordination of multiple teams
	Reaction to external environment

4. Discussion

From the analysis of these results, a discussion can be had. As this paper is mainly a literature review there are many points that can be drawn from these analyses and utilized for the new process.

The prototyping process can be divided into both “business” and “engineering” components, which are widely considered in tandem with each other despite their vastly different considerations. The “business” facet includes bigger concepts (such as lead times and efficiency) which can be pulled from a larger body of work for prototyping, while the “engineering” side utilizes less solid documentation and thus is too diverse to have many common strategies for processes of different prototypes (Christie et al. 2012).

Literature often considers prototyping important, but it is rarer to find a systemic approach demonstrated anywhere. This is why prototyping can be considered a “primarily intuitive and iterative” process, which easily leads into an inefficient process. Another factor leaning into the inefficiency of prototyping processes as a whole is that the production of prototypes correlates directly with costs for materials and labour (Schork et al., 2018).

For creating improvements for COMPANY A’s multidrive prototyping system, it is necessary to consider the workings of multiple moving parts. These include the current process, the ideal situation, and the path in between that balances the possibilities of improvements while not compromising the current conditions that do work.

An issue with doing anything new, especially for a company, is that everything requires “frontloading”, which means that costs must be put into materials and manufacturing before finding out if it will pay off due to success (Schork et al. 2018). This can prove a risk to bigger firms, which is why the prospects of each solution need to be considered gently.

The most straightforward commencement of solving issues within the current working of COMPANY A’s prototyping process is to investigate the aforementioned bottlenecks described in the previous chapter even further. Providing solutions to these issues would fix what have been identified as the largest issues in the process. This section will be further divided into two subsections, one describing possible and realistic solutions while the other will focus more on what is needed for the ideal situation, including more radical solutions.

4.1. Improvements to the current prototyping system

The way to start building a streamlined process is to break the earlier system down. Starting the entire process with the R&D team is reasonable, but it causes misjudgements in the operations further down the line. A clearer ability to judge the time needed for the process in the production line would be convenient for the entire process. This could be eased by having some sort of demonstration available of the possible issues that may rise (e.g. material acquisition) and the ability to assess the probability of these happening, coupled with the knowledge and talent of being able to determine a good timing for the final testing of the built cabinet prototype.

The problems that arise with this proposition is that no one has the ability to see the future, and thus it is rather impossible to assume someone would be capable of gauging the time needed for the entire process based purely on the customer's requests. The solve to this could be something along the lines of having a more flexible date for the final testing.

The realistic vs unrealistic solutions have been divided based on what was found in the literature and considered in tandem with COMPANY A's current operations. The goal is to provide both realistic and idealistic solutions for the firm to consider.

4.1.1. Realistic solutions

The realistic solutions to the problems are ones that are attainable and thus more reasonable to implement into the current process.

One of the possible solutions provided is for the problems with the current software. MIS does not recognize the prototyping process due to the lack of production order -number, which causes the issue of having to manually keep track of work steps. A fix to this would be to create a unique software purely for prototyping or achieve this by modifying a branch of the current application of MIS to be used for prototyping projects.

A full restructuring of the programme would take some time, which could cause some setbacks within the process but when done well it would save time and effort in the future. This could also require the subcontracting of another company or branch to create a new software, causing more expenses for the company in this search for the ideal.

A seemingly more effortless resolve is on the question of the BOM. The struggles described with it are mainly engaged with scheduling and therefore the acquisition of materials. Having the BOM attainable before the whole project moves to the production line would solve this, but it would require that the R&D department would need to compile the BOM and get it to the production team – even with just the possibility to view what will need to be attained for the project at hand.

The problem of having a cabinet standing still for a long time while issues surrounding it get solved could be solved by working parallelly throughout the process. This means that different people would be working on the same part of the project at the same time, which could cause oversaturation of the process, but would avoid standstills in the production line. These parallel pieces of the project being worked on would not have to be the exact same causes, but all working on different components of the final product (Schork et al. 2018). This parallelization works in tandem with the convergence of different titles and teams within projects mentioned earlier as Yu et al. (2018). This is demonstrated in Figure 2 below.

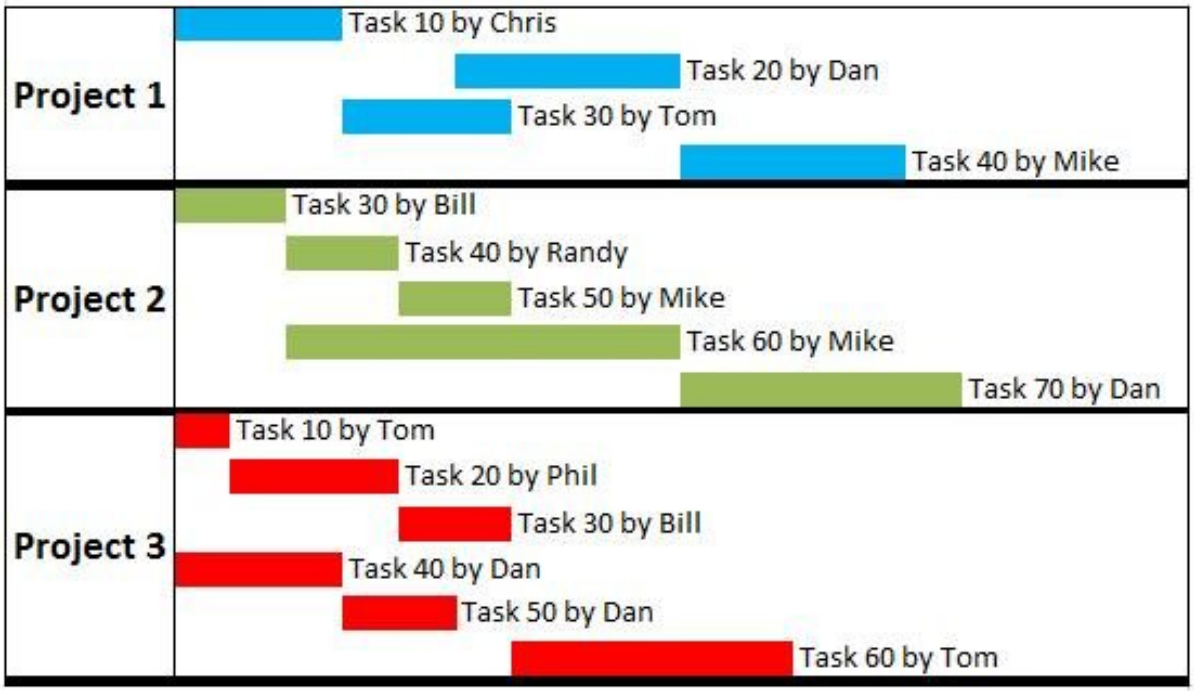

Figure 2: Example of a software used for multi-project management/parallelization, https://optisol.biz/multi_project_scheduling/

4.1.2. Idealistic solutions

The more idealistic solutions are the ones that have been deemed less attainable throughout this research.

The problems to be tackled are the bottlenecks mentioned earlier. The unattainable solutions will showcase the marriage of the ideal situation within the prototyping process.

Interpersonal communications are always changing due to factors that are convoluted and influenced by external elements. This does not mean that good communication is impossible, but that humans are complicated beings. This is why seamless communication is considered an idealistic solution.

95% of all problems that happen within any sort of projects are due to substandard communications. A large portion of this belongs to project management, who must take care of their communication skills while presenting facts and details appertaining to the project (Baker, 2007). This could be solved with better communication strategies, but as seen with other large projects, these can still fracture.

The issue with the possibility of having all the needed materials ready for the prototype at the lot when the project is scheduled to start, is that the procurement of materials is not done by COMPANY A, but by another company subcontracted to deliver to the factory. The only thing that can be done for this is the aforementioned solutions for the BOM, but this also does not clear up any and all issues that are possible within material acquisition.

4.2. Basis for a new and improved process

The foundation for the revised and modified prototyping process starts from finding the differences between a well-working process's justifications and the one currently used at COMPANY A.

The best working ways found in the literature review were buried deep in papers and research. The broader literature has weak observations of prototyping processes, often regarding the "business" and organizational sides of the process instead of focusing on the implementation for projects.

At the core of expertise in the field is communication, engagement, and a profound undertaking of working across the expected boundaries of the organization. This means that the leaders of the project need to also be capable of engaging with the employees on the production line about the process (Prahalad et al., 1990).

A question that gets raised with the possible solutions is whether hiring more people for the prototyping production line make the whole line more productive or just more crowded with everyone waiting if there was a standstill in production. The process of hiring is hard and time consuming, using up resources that could be used for the actual process. There are also many different qualities that need to be considered, and Katiraee et al. (2023) talk about hiring for the organization versus hiring for the job. This needs even more effort and thought from the project leaders. Another factor to consider is the necessity of having a diverse skillset. This once again needs different considerations while hiring or searching for people.

Another concept that resources need to be used towards is employees being taken care of so they do better work. “A lack of attention to workers may lead to an increase in workers’ fatigue and accidents, which is risky for the company in terms of efficiency and cost” (Katiraee et al. 2023, 6951/13). Another positive influence to the workers’ motivation is if they are allowed to participate in analysis of the work being done. This means that if employees know what is happening, they will perform better. Having the employees from the production line be in meetings between the project managers would make sure they were kept happy and safe.

The possibility of merely focusing more resources onto the prototyping process is difficult as the factory still manufactures their usual products, which are successful worldwide. There is no reason to stop doing these things as stable products just to pour resources into a process that does not have a stable basis. Due to this, a problem that still exists is that sub-units of organizations such as production lines encounter adversity in trying to abandon old and prevalent routines (Prahalad et al. 1990).

Undeterred by this, changes in manufacturing requirements are considered to usually be unavoidable. Mukherjee et al. (2000) mentions a “focused factory strategy”, which consists of persistent manufacturing routines and absorptive capacity for adaptation of a factory. It is mentioned that considering what empirical evidence exists on the subject suggests that companies that enlist this more focused strategy often achieve better results. In this context,

a focused factory means one with “repeated executions of a limited number of routines that the production line remembers by doing” (Mukherjee et al. (2000),145). This creates an issue with prototyping and innovating in general, as each project can vary. The idea to be pulled from this is that everyone concerned with COMPANY A’s prototyping process should have the knowledge of a varied spectrum of different designs that may show up. These can not be “practised” in the way mentioned earlier, but can still be utilized for training.

“New” knowledge refers to “a shared understanding of the change in manufacturing requirements and the consequent responses that a production line will need to undertake in order to create routines that meet the new requirements.” (Mukherjee et al. (2000), 144) This means that with every new process the current infrastructure, such as routines and existing elements, needs to be re-examined.

5. Conclusions

By examining current processes and identifying principal bottlenecks, this thesis will work as the background for piloting a new prototyping process for COMPANY A's multidrives. As well as addressing the drawbacks of the former method, the final procedure aims to better fit the operational objectives of the firm and user's requirements.

The practical contributions of this paper will ease the work done at the firm, as well as guide future processes.

5.1. Implementation of a new prototyping process

Considering COMPANY A as a company along with the themes uncovered by this paper, a more streamlined prototyping process is aimed to be created.

All good things start from a blank slate. It is apparent that an important element of a firm's proficiencies in the field come from the organizational standpoint, and of knowing or learning how to coordinate varied production skills along the production line. This means that the project manager should have enough knowledge of the production line to be able to interact with the project expertly. Failure to do so increases the possibility of harm to both the employees as well as the company (Prahalad et al., 1990).

The competence of a production line is often related to the routines that are implements at the line. Technological computation, information transfer, flow of materials, and manufacturing support are considered routines of a production line that need to be executed well (Nelson et al., 1982). These can thus be considered some of the main elements of any production line, and implemented into this prototyping process.

As discovered before, there are some realistic solutions unearthed by this research that could be implemented at the company's factory. These solutions bear their own challenges as well, but prove potential substantial improvements to the current process.

These include creating a software for prototyping projects to use, as the current MIS program does not recognize these. This could be done simply by reprogramming the current software to have a subsection for prototyping projects.

Another bottleneck that can be solved is issues with the BOM and further material acquisition. This could be fixed by the production line having access to the BOM earlier, as well as the possibility to order materials of interest ahead of time.

Considerably more idealistic solutions were also discussed. These are solutions that prove to be difficult or nearly impossible to obtain.

One of the clear ideal solutions is seamless communication. The issue with this is that humans are flawed and thus will always have some sort of lapse in judgement one way or another. This is also apparent in the fact that people can not read each other's minds in hopes of getting clear information. To make this a more realistic solution, specific guidelines could be created for communication within prototyping projects.

Ultimately, this thesis explores the possible improvements to COMPANY A's prototyping process through analysis of the current process as well as literature surrounding the subject. Together, these combine into a list of proposed solutions to be forwarded to the company in hopes of bettering the process.

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