PUBLIC SUMMARY OF THESIS B-IEM; DANIËL WONINK S2810247

MINIMISING DELAYS BY OPTIMISING ENGINEER TRAINING DESIGN

Introduction

The thesis aims to delve into Strategic Workforce Planning (SWP) of Company X. Where the focus is on the identification, analysis and recommendations regarding competencies and the related training design. By continuously developing their SWP, Company X can ensure that it has the right skill set in place to handle production and achieve growth. “Strategic Workforce Planning … is core to any institution that aims to sustain itself over time” (Sokol, 2024). SWP serves as the link between human resource management and the strategic plan of Company X, which includes all kinds of aspects like the move rate. A thorough study by Sapients Insight Group states that the business outcomes of organisations without SWP and with SWP are 2.88 and 3.16, respectively, on a scale of 5 (Harris, 2022). Indicating the relevance and need for the existence of human resource management, thus this thesis provides valuable insights into the competency landscape and recommendations to enhance production by reducing delays.

For Company X it is of great importance to have optimal production efficiency, which is hindered by delays of any sort. The thesis focuses on the ultimate goal of minimising the difference between the actual costs and the estimated costs. This will help Company A to be more profitable. As all extra actual costs are directly deducted from the profit, optimising this difference has the potential to improve business performance greatly. This is beneficial for both financial stakeholders and others as the saved goods can be used for other purposes.

Core problem

To reduce the deviation between the estimated and actual costs, this research focuses on delays, which is one of the main reasons that the costs turn out higher than expected. A standstill leads to expensive idle time for machinery and the engineers sometimes have to clock "waiting time", which is just wasted. A primary cause of the delays is the unavailability of trained engineers. Company A often experiences delays in production because of the planned or unplanned absence of engineers. If, for any reason, too few engineers are (directly or indirectly) available to execute an action, then the other engineers cannot continue with their scheduled actions and have to wait till someone is available to execute the task. Likewise, many competencies exist and tasks can be seriously dependent on the precedent tasks.

An effect greatly contributing to this problem is that, at present, the management has no clue when they should train who and for which competency. Presently, no structured approach for training existing or new engineers exists. Some time ago, one of the production leaders aimed to analyse the landscape in terms of competencies by creating a competency matrix. Unfortunately, this was never properly executed by the production leader who replaced him shortly after. Despite the initial plan of moving towards a SWP, a lack of priority made that the attempts were thwarted. Now some employees desire to use this matrix regularly but are unable to due to the outdated information. Consequently, the scheduling of new engineer training is based on the opinion of production leaders.

The severity of the delays grew due to the rapid growth in the production rate. A few years ago manufacturing was possible with a handful of engineers who knew the process. Moreover, a problem cluster was created to illustrate the core and action problem and their relation visually, see figure 1. At the top of the diagram, the action problem is displayed, which is the problem that costs turn out higher than budgeted. This is to be optimised by solving the core problem at the bottom of the figure. The core problem has been identified using several rules from Heerkens and Van Winden. Specifically, the pneumonia rule states that we should not consider causes that do not relate to our solution and exclude factors that cannot change (Heerkens, 2017).

To limit the scope of the research we deconstruct the higher costs to those costs caused by idle machinery and clocked waiting time for engineers. Delays of many sorts cause those costs, mostly external and internal factors that cannot be changed, for example, delays in material delivery and equipment failure. The unavailability of trained engineers is therefore selected as the delay to solve. This is partly caused by an unreasonable amount of absence, which is considered to be an irrelevant cause due to the pneumonia rule. Ultimately we find the core problem to be defined as follows:

“The management of Company A has no insight into when, who and for what competency they should train (new) engineers”

Part of the core problem is the lack of documentation concerning the competencies, which have not been mapped due to other priorities. Neither the required competencies for production nor the present competencies in the engineering team have been mapped. Furthermore, within the problem cluster and the thesis the term “training design” is used to describe the combination of knowing who to train, when to train and for what competency.

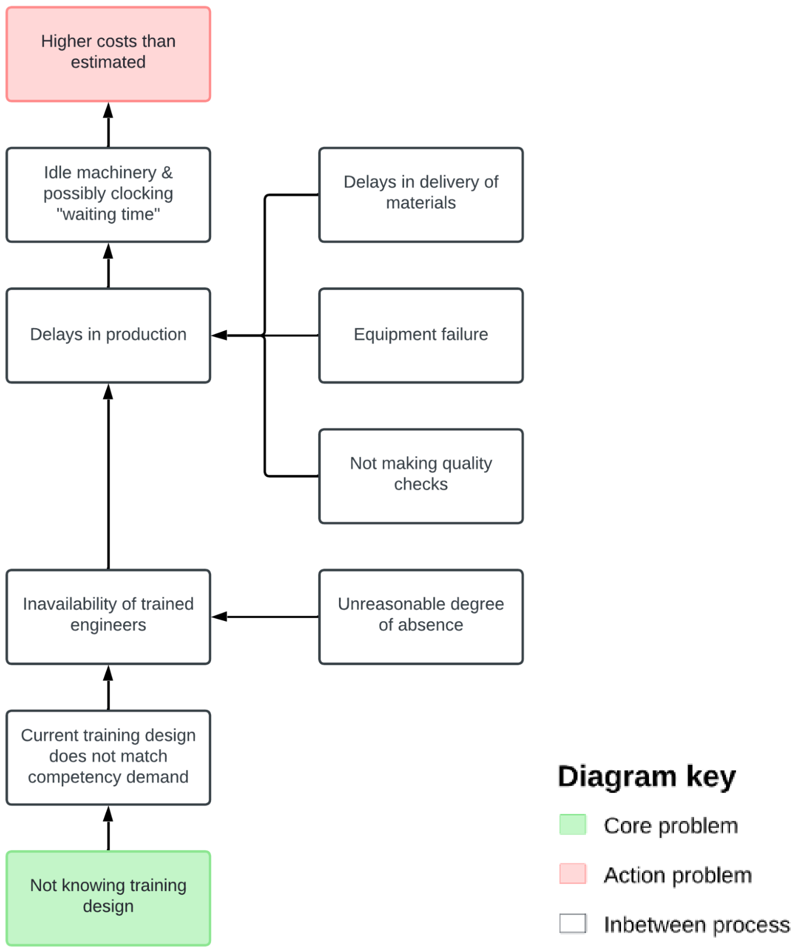

Figure 1: Problem cluster

Research design

An analysis of the competency landscape, complemented by a framework will provide the management with the demanded knowledge to make decisions regarding the engineer training design. To shape the research leading up to these deliverables, the following research question has been formulated:

"How can a systematic approach enhance engineer training design to minimise production delays due to the unavailability of engineers?"

The research design consists of two primary sub-questions, each further divided into additional sub-questions. The first primary sub-question is as follows:

"How do the production competency requirements align with team skill sets, and how can this be developed into a competency matrix?"

The goal is to perform an analysis of the production process, specifically looking at competencies. The primary research methods will be document reviews and interviews to map the process, creating a detailed overview of the process flow and competencies and turning this into a competency matrix. After this step, it will be possible to analyse the current production process and identify the first pitfalls. The result of this sub-question is the basis for the final recommendation in terms of engineer training design. Furthermore, it also provides significant value individually, as the executed analysis and overview will help the management with making decisions regarding SWP.

The latter sub-question is regarding the implementation of mathematics and is as follows:

“How can mathematical modelling be utilised to optimise the decision-making process for training scheduling, by aligning present competencies with production requirements?”

The sub-question requires a mathematical model to complement the competency matrix. Based on the IEM background and the nature of the assignment, an integrated framework of models has been selected as the base for this tool. It allows for a combination of approaches to provide an objective value for the individual production processes and associated competencies.

Reliability and validity

The level of reliability in a research refers to the consistency, "Reliability is the extend to which data collection techniques will yield consistent findings" [18]. Based on the points mentioned during the research design we can conclude that the research is highly reliable. The research is based on a multi-method approach, consisting of a literature review, a document review from the company and checks with experts (process-driven research). The different sub-research questions are very much inter-linked and based on the results of the previous question. So if every element is integrated, the reliability of the process should be assured. The reliability will be further assured due to the transparency of the thesis, peer review of the work and credibility of the sources. Despite the confidentiality of the report, the research will be fully replicable.

The validity of research can be defined as: "the extent to which data collection methods accurately measure what they were intended to measure" [18]. For this assignment, the expert panel and company data protect the model’s quality. The internal validity is protected by the fact that everyone within the company would aim to provide accurate information since the result of the research is in their favour. The minimisation of delays entails that Company X will be able to deliver their products quicker and this has a few positive impacts. Doing an internship at Company X shows that it can be frustrating for engineers to wait for others to be available in order to continue with production. Discussions with the different Factory Engineers (FE) and Production Leaders (PL) show that a structured engineer training design and a specialised framework will have a positive impact on the morale of the engineers.

Perspective

The theoretical perspective of the thesis will be used as a lens through which the research is interpreted and put into context. Showcasing where the research fits between previously published literature and which connections it has. Some solutions to resource allocation are well established in literature (Hans, 2012), (Jnitova, 2021), (Turan, 2021). Those cover the mathematical element of optimising the distribution of workers over locations or jobs. However, the training design perspective is not covered in the papers. In other words, plenty of solutions exist to schedule workforce capacity optimally but none focus on scheduling workforce education to handle demand. Thus making it relevant to contribute by investigating this lacking aspect. To fill a gap in the existing literature by addressing the scheduling of workforce training instead of scheduling the workforce after training. The research extends the scope of existing research by delving into a different and new element of resource capacity planning. Since it is a separate element, it can serve others to gain a more comprehensive understanding of resource capacity planning.

Analysis of literature

The literature review has been conducted to obtain a base framework to use as the foundation to map the process flow with competencies. This means that it should enable the showcase of a production process with linked skills or competencies clearly. Also, it adds value if the process is displayed so that it is understandable for everyone, not just the maker.
Several methods were suggested by the literature review to use for mapping the process flow and competencies. Value Stream Mapping was an option but was eventually rejected because of its complexity. It requires all flows of material or information to be tracked as well as the duration, before a list of competencies is extracted. This extends beyond the scope of this assignment and is considered irrelevant (Rodas, 2021). Furthermore, mind mapping is considered a possible model for displaying the competencies. Even though it does look really clear to draw connections between the different types of competencies, it is not ideal for this process. Since it lacks the possibility of clearly displaying the entire production process without and not just the competencies (Takey, 2015). The best fit turned out to be the Business Process Model and Notation, specifically the one approach that

integrates competencies. BPMN is a strong mapping tool due to its broad range of applications in the business industry, and its strength of incorporating processes from different fields. Furthermore, the BPMN model allows for flexibility in terms of scope, type of processes and integration. Which means that the BPMN can be adjusted to the needs to a considerable extent. Adding competencies to the BPMN works straightforward, by adding annotations connected to the activities or decision points with a dotted line. Within the annotations, symbols or abbreviations are often used to make it more readable, for example, A1, B2, and C3 as codes for different competencies (Pawełoszek, 2017).

Solution sub question 1

The research continues with a document review, delving into the databases and outdated overviews at Company X. Which happens due to a lack of priority and responsibility, leading to no updates. Those responsible acknowledged that plenty competencies no longer exists as well as for engineers who are still present at Company X. These documents form a basis for the expert interviews, where it was directly found that the outdated overviews were indeed not used. During those interviews, the number of competencies per overview was reduced with 54%.

An important note is that not every basic skill is considered a competency for this research. Certain skills are seen as the bare minimum for someone to start working at Company X and are therefore neglected in this research and were also neglected in the previous documents.

Different lists of competencies were developed and facilitate a ground for open, axial and selective coding. With the purpose of creating better-defined (new) concepts which form a general list of all present competencies at Company X.

The open coding segment starts during the expert interviews already, after which the data needs to be grouped together and analysed. The important data needs to be filtered out of all qualitative data gathered and given a code. Finally, a list is developed including all competencies mentioned during the expert interviews.

The next step is to attach labels to the different competencies and divide them into categories. The goal of this research is to do so by grouping them based on identical competencies. In other words, grouping the competencies from individual products if they have the same qualification. This allows us to combine many of the same or similar skills and create a much more compact list. The results are visualised in a matrix with the different products on another axis of the competencies. Frequent discussions with production leaders guaranteed the validity and removed plenty of errors caused during the data collection.

Lastly, selective coding takes place to assign a core category. Since the aim of this question is not to find one core category. It has been decided to assign categories to groups of different competencies. In a way where each product has a minimum of four and a maximum of seven categories. This originates from a constraint of the management, which prefers an overview from categories. Mainly because this allows to educate engineers within a specific category based on the overview that the final competency matrix will provide. For instance, if the move rate continues to increase rapidly it can be useful to train engineers for all tasks related to a category. Such that this engineer will develop all skills related to the said category, increasing the quality of the final matrix by making it future-proof.

With the final list of competencies and associated codes at hand, the BPMN models are constructed and validated by the experts.

Another set of expert interviews was conducted to gather the necessary information regarding the skill sets of the engineers. Using different matrices within Excel, the data is stored and managed. Each competency for each engineer is given a score from 1 to 4. Where 1 indicates the engineer is not competent to execute a task. A 2 states that the engineer is in training and can execute a task supervised. From 3 onwards, the engineer can execute a task unsupervised and at level 4 the engineer can train others as well.

To conclude the first sub-question, a framework is developed to provide the management with an overview. Different data merging techniques and overviews are utilised to transform the data to the required format.

The objective of the framework is to display the relevant competencies of engineers in a visually appealing manner which is easy to access. For that reason, the framework should allow the user to view all details related to competencies but the first glance should not be an overload of information. Additionally, a few characteristics are added to the solution to enhance the quality in terms of decision-making.

Consisting of a score per engineer regarding the significance of their presence in terms of the number of competencies trained. Indicating which engineers form a higher risk of delay if they are absent, as well as showing which engineers might benefit from more frequent training sessions. Secondly, a holiday simulation is added which allows the user to see the impact in terms of availability when a certain combination of engineers is absent. Finally, a radar plot stimulates the quick processing of information by visually indicating which competencies are critical.

Solution sub question 2

The previous analysis provides the management with an overview of their strong areas and weaker areas in terms of competencies. A tool has been developed to create a deeper layer, enabling the management to make decisions based on the criticality of competencies and predicted results. This chapter describes how a model contributes to the quality of the matrix during the decision-making process.

The results from literature review describe the analysis of existing models, in the field of workforce planning, training design and resource allocation. The focus was on identifying the gaps and comparing relevant aspects. Three main models were considered, namely dynamic programming model, linear programming model and the markov decision process model.

The dynamic programming model is robust and of high-quality, it is focused on solving an objective function by optimisation. However, it assumes dependence of preceding tasks, which makes it unsuitable for the production process of Company X due to the nature of the process and operational methodology.

The linear programming model does not include order-based decision-making and allows optimisation from an overall perspective. However, it requires all constraints and the objective function to be linear, which is not possible for this research.

Finally the markov decision process considers stochastic situations and makes decisions on discrete points in time. Its probabilistic nature is a great improvement, and dynamic states offer a great alternative to the previous models. However, the state and its state transitions required for a Markov decision process do not fit the problem at hand.

In conclusion, none of the modelling techniques is a suitable fit as a base model for this research due to the properties of the production process. The final mathematical model will be a combination of probabilistic, stochastic, and optimisation models, addressing the problem without a time-dependent or iterative element and involving randomness in predicting the future availability of engineers.

With the suboptimal engineer training design, the following model is proposed. The overruling motivation behind this tool is that besides the competency analysis, there is also a piece of advice on what to train more engineers on.

To fulfil this motivation, the model will provide some ranking to the different competencies. Such that if a new engineer joins, it can be easily concluded what training should be focused on. This ranking will be provided by calculating the expected delay per competency. For this, the assumption is made that each competency behaves individually, or in other words, an engineer can only have one competency. In reality, this is known to be incorrect, however, one can assume that if the production process is in need of competency Y. Then an engineer who is granted that competency will always aim to work on the task that is at hand, instead of working on something else.

The concept includes that each competency has its own mathematical model executed to gain a value. The model is ran individually based on some different parameters, while a lot of others stay the same. Due to the complexity, this has to be separated, but simultaneously it is the best approach to create a ranking of the different competencies. With additional formatting, the final model is implemented in the existing framework which combines the two powers.

Results

Following this, conclusions can be drawn regarding the criticality of the competencies based on the output of the mathematical model. Providing the management with the optimal engineer training design with the current situation in mind, as well as an adaptable framework for the future.

Robustness

Standardised data collection methods like document reviews and expert interviews, both at Company A and the University of Twente, improve the reliability of the research. Additionally, the entire research process was documented in a transparent manner, including audio recordings of the interviews and raw data collections.

Regrettably, validity of results could not always be guaranteed. The analysis is relatively valid due to the frequent verification of the collected data with different parties within Company A. However, there is a gap between the IEM paradigm and the metalelektro industry in terms of translating the phenomena to competency phrasing. Moreover, sub-question 2 knows some challenges regarding the generalisation of competencies, as opinion of engineers also collided, and the decision is ultimately left to the production leader. The competency analysis does not imply any direct actions, the purpose of the framework is to assist during the managing and decision making process for the management which can be executed well.
Finally, the research encountered several limitations, as the initial plan of the research in terms of adapting a model was too ambitious and not a fit for the nature of the production process. Another limitation is the available data sets, as Company A does not have data ready on the competencies a lot of assumptions were made. Of which it is known that they do not represent reality, partly also due to the nature of

the production process. These incorrect results can be justified as the final output provides advice on comparing competencies. It should be noted that this cannot be used to accurately predict the probability of delays.

Conclusion

Based on the advice coming from the developed mathematical model, a certain number of competencies are critical. However, due to the combination of the time constraint of this assignment and the lack of exact data measurements the proposed results could not be compared.
The demand of the management is fulfilled by providing an analysis and framework to display the competency landscape at Company A.

Future research could significantly benefit Company A, by optimising the SWP especially regarding the outlook on growth for the company. The competency analysis and matrix provide a solid foundation, but an improved, more complex model would be necessary. Alternatively, it could be more beneficial to neglect the adoption of a mathematical and focus on the optimisation of SWP by quantifying competency descriptions or moving towards a series production that works based on teams or competency categories instead of individual competencies. On the short term, a valuable addition would be to examine the minimum number of engineers Company A needs per competency, which is opinion related at the moment but might be quantifiable.

References

Hans, E.W., van Houdenhoven, M., Hulshof, P.J. A Framework for Healthcare Planning and Control. Springer US, 2012. DOI: 10 . 1007 / 978 - 1 - 4614 - 1734 - 7_12

Harris, S. “A how-to guide for workforce planning beyond the Great Resignation”. In: Human Resource Executive (Mar. 2022). URL: https://hrexecutive.com / a - how - to - guide - for - workforce - planning - beyond - the - great-resignation/

Heerkens, H., van Winden, A. Solving Management Problems Systemetically. Noordhoff Uitgevers, 2017

Jnitova, V., Joiner, K., Efatmaneshnik, M., Chang, E. “Modelling workforce employability pipelines for organisational resilience”. In: International Journal of Engineering Business Management 13.30 (Mar. 2021). DOI: https://doi-org.ezproxy2.utwente.nl/10.1177/18479790211004010

Pawełoszek, I. “Process-oriented approach to competency management using ontologies”. In: Federated Conference on Computer Science and Information Systems 11 (Sept. 2017), pp. 1005–1013. DOI: 10.15439/2017F441.

Rodas, S., Siguenza-Guzman, L., Llivisaca, J. “Lean Manufacturing for Optimizing Operational Processes in a Bicycle Assembly Line”. In: (2021), pp. 113–128

Sokol, M.B., Tarulli, B.A. Strategic Workforce Planning: Best Practices and Emerging Directions. Oxford University Press, Mar. 2024

Takey, S.M. de Carvalho, M.M. “Competency mapping in project management: An action research study in an engineering company”. In: 33.4 (2015), pp. 784–796. DOI: https://doi.org/10.1016/j.ijproman.2014.10.013.

Turan, H.H., Kahagalage, S.D., Jalalvand, F., El Sawah, S. “A multi-objective simulation–optimization for a joint problem of strategic facility location, workforce planning, and capacity allocation: A case study in the Royal Australian Navy”. In: Expert Systems with Applications 186.30 (Dec. 2021). DOI: 10.1016/j.eswa.2021.115751