Frameworks for Strategic Fit of Planning Environments: A Case Based Exploratory Study

Sven-Vegard Buer, Jo Wessel Strandhagen, Jan Ola Strandhagen, and Erlend Alfnes

Department of Production and Quality Engineering, Norwegian University of Science and Technology, Trondheim, Norway
{sven.v.buer,ola.strandhagen,erlend.alfnes}@ntnu.no, jostr@stud.ntnu.no

Abstract. In this paper we have evaluated existing frameworks for investigating the strategic fit of a company's characteristics and their planning environment. Frameworks from Jonsson and Mattsson [1], Schönsleben [2], Lödding [3], and Olhager and Rudberg [4] were investigated. Based on a number of these frameworks, an integrated framework for mapping the planning environment is developed. The framework presents 30 variables that are considered important in order to map the planning environment of a manufacturing company, and the framework can be used as a benchmarking tool. The framework has been tested through a case study where five Norwegian manufacturing companies have been investigated.

Keywords: planning environments, strategic fit, planning and control

1 Introduction

As business models are different and on the change for many companies and value chains, the need to assure the strategic fit of planning environments is more important than ever [5]. In this research, we have investigated several frameworks for mapping planning environments and tested an integrated framework through a number of industrial cases. Based on Olhager's [6] and other authors perspective of the customer order decoupling point (CODP) we have seen the need to identify key characteristics to map, analyze and use as decision support to select CODP placement and planning and control principles and mechanisms. Jonsson and Mattsson [1] argue that knowing the actual planning environment is fundamental in order to use the appropriate planning methods for the specific environment. This is supported by Schönsleben [2], who also mentions that planning environment variables may be used for comparison of results within the company or the supply chain to reveal potential problems for efficient logistics. He also states that in order to compare performance indicators among different companies effectively, these variables should be taken into account.

The main purpose of the paper is to analyze the existing frameworks. These are compared, and the different characteristics from the frameworks are merged into an integrated framework. This framework is then applied to a number of case companies to test its practical applicability.

The methodology applied in the paper includes a literature study to examine the importance of planning and control and identify existing frameworks for mapping planning environments. Furthermore, case studies of five different manufacturing companies have been conducted to test the integrated framework.

The paper is structured as follows: Chapter 2 will introduce planning and control and outline its importance for manufacturing companies. Next, Chapter 3 introduces the frameworks investigated and tested in this paper. The frameworks are then combined to an integrated framework in Chapter 4. The integrated framework is presented in Chapter 5 with the results from the testing on case companies included. In Chapter 6 the applicability of the integrated framework is discussed. A conclusion of the paper is provided in Chapter 7.

2 The Importance of Production Planning and Control (PPC)

In general, production planning and control (PPC) can be described as the activities required to match supply and demand [7]. It is concerned with scheduling, coordinating and organizing operations activities [8]. Vollmann et al. [7] defines *PPC* as the tasks required to: "… manage efficiently the flow of material, the utilization of people and equipment, and to respond to customer requirements by utilizing the capacity of our suppliers, that of our internal facilities, and (in some cases) that of our customers to meet customer demand". The importance of PPC for a company's logistics performance can be illustrated by the consequences of poor design of the PPC system, as poor PPC performance often has been a major cause of company bankruptcy [7].

Several authors (see e.g. Vollmann et al. [7] and Lödding [3]) emphasize the importance of production planning and control in order for a company to be competitive and profitable. Moreover, Jonsson and Mattsson [1] examined the implications of fit between the planning environment and PPC methods and found that the applicability of PPC methods differs between environments. Vollmann et al. [7] states that an effective PPC system can contribute to competitive performance by lowering costs and providing greater responsiveness to the market. The link between PPC and performance is also addressed in Olhager and Selldin [9] where the hierarchical planning levels *sales and operations planning* and *master production scheduling* are found to have a significant and positive mediating role for improving operational performance in manufacturing environments that are characterized by market uncertainty. Further arguments in Vollmann et al. [7] highlight that both the production processes in a company and the market requirements have implications for PPC design.

The CODP is the point in the manufacturing value chain for a product where the product is linked to the specific customer order. Thus, it is the point that separates production based on forecast and plans from production based on an actual customer order [6]. The positioning of the CODP has great implications for a company's manufacturing strategy, as different approaches to and methods for planning and control is needed upstream and downstream of this point. The position of the CODP is also used to classify the production environment. Vollmann et al. [7], Olhager [6], and Schönsleben [10] all uses a classification that consists of four different manufacturing situations; Make-to-stock (MTS), Assemble-to-order (ATO), Make-to-order (MTO), and Engineer-to-order (ETO). Olhager [6] investigates the most important factors affecting the positioning of the CODP and divide them into the three categories *market, product,* and *production characteristics.* Forward or backward shifting of the CODP to better correspond to the present factors may give increased competitive advantage.

These findings inspired us to map and evaluate existing frameworks for mapping the planning environment and identify which variables that are of importance.

3 Frameworks for Mapping the Planning Environment

The framework by Fisher [11] for matching the supply chain with the end products produced in the supply chain can be a starting point for investigating the strategic fit of a company's characteristics and planning environment. The idea of matching efficient supply chains with functional products and responsive supply chains with innovative products gives a general overview of how the logistics operations of a company should be organized to be able to deliver its products to the market place in an applicable manner. Even though categorization of products in only two different groups (functional and innovative) may not be adequate for a company with a large variety of complex products, which may be both functional and innovative to certain extents, this framework emphasizes the importance of matching the way operations are organized and carried out with the products that are produced and sold as value to customers. In other words, Fisher [11] addresses the issue of matching logistics processes with the market requirements in question.

There exist several frameworks for investigating the strategic fit between a company's characteristics and the planning environment. Those who have been examined in this paper are frameworks by: Jonsson and Mattsson [1], Schönsleben [2], Lödding [3], and Olhager and Rudberg [4].

Jonsson and Mattsson [1] conducted a conceptual study and a survey of 84 Swedish manufacturers to examine the fit between the planning environment and production planning and control methods. Jonsson and Mattsson [1] argue that the fit of production planning and control methods is dependent on characteristic features related to product, demand, and manufacturing processes. Of the examined frameworks this framework consist of the most variables, 21 in total. For this reason, this framework has been chosen as the basis for the development of the integrated framework. It has further been complemented with the three other frameworks to cover an even broader scope of variables. This approach is supported by Jonsson and Mattsson [1], which points out that a larger number of variables for mapping the planning environment (especially related to the manufacturing process and shop floor control) will be of great value.

Schönsleben [2] argue that the choice of a suitable concept of production planning and control is dependent on characteristic features describing the customer, product or product family, the logistics and production resources, and the production or procurement order. Especially the category *'production or procurement order'* includes variables that are not present in Jonsson and Mattsson [1]. Hence, including these variables will expand the scope of mapping variables.

Lödding [3] developed a framework for mapping variables affecting the choice of manufacturing control methods. It does not include a categorization of the variables, and compared to both Jonsson and Mattsson [1] and Schönsleben [2] the number of variables is relatively low. In addition, Lödding's framework is aimed at the production control part of PPC as opposed to the two mentioned frameworks above, and the variables presented are therefore more related to shop floor control. Due to the relatively low number of variables considered in this framework, it can be argued that it may not be sufficient for a complete mapping of the planning environment. On the other hand it includes certain unique variables, hence it can complement Jonsson and Mattsson's [1] framework, which, as stated previously, has a need for more shop floor control related variables.

Olhager and Rudberg [4] developed a simple framework where they present the different PPC levels and define what they consider the most important variable for each level. This means that this framework only consists of five different variables, but all are considered important. Most of the variables presented here have been covered by other frameworks, except for *planning points*. This framework is certainly not comprehensive enough to map a planning environment solely, but gives input on some of the most important variables.

A comparison of the frameworks examined in this paper shows that they are partly overlapping, and partly include different mapping variables. Furthermore, the different frameworks use different categories for dividing the mapping variables. By using the framework of Jonsson and Mattsson [1] as the basis, and complementing it with the mentioned frameworks, an integrated and more comprehensive framework can be developed. The development of the integrated framework is described in Chapter 4.

4 Towards an Integrated Framework

In order to create the integrated framework, we investigated and evaluated some of the most cited existing frameworks for classifying production planning environments. Relevant variables were extracted from the frameworks. In addition, to make it easier to classify the companies and to use the framework for comparison of different companies, values, which describe the different possible states, are given for each variable. Some of these values are defined in literature, while others have been defined while developing this framework.

The framework proposed in this paper consists of a total of 30 different variables that help describing a production planning environment. The variables are grouped into three main categories: *product, market,* and *manufacturing process related,* a classification scheme used by among others Olhager [6], Hill [12], and van Donk and van Doorne [13]. The framework should be easy to use, and should not require that the user have extensive detailed knowledge about the production process at the company. The following section presents the 30 variables, describes briefly the meaning of each variable and the different possible values where it is considered necessary. The framework is presented in table 2.

Product related variables

The *CODP placement* says something about how much of the manufacturing of the products is finished prior to the receipt of a customer order [1]. *Level of customization* refers to which extent the customer can specify the properties of the delivered product [1]. *Product variety* represents the number of possible product variants that the production firm is delivering [1]. Some companies that deliver fully customer specific products, for instance ETO companies, will naturally have a high number of product variants. *Bill-of-material (BOM) complexity* represents how many levels the typical bill-of-material in the production consists of, and the typical number of items on each level [1]. *Product data accuracy* is referring to the data accuracy in the BOM and the routing file [1]. Inaccuracies in the BOM may lead to differences between planned and actual material usage, and incorrect data in the routing file could lead to a sub optimized production layout. *Level of process planning* is the extent to which detailed process planning, such as systematic determination of operations and their sequences, is carried out prior to the manufacturing of the products [1]. The different states related to this variable in the framework ranges from none, which means that they plan the production as they go, to a fully designed process where every operation of the production are planned in detail before the production starts.

Market related variables
P/D ratio gives the ratio between accumulated production lead-time and the delivery lead-time required by the customer [1]. This is an important parameter to look at when deciding where to place the CODP. Is the production lead-time short enough to meet the customer requirement, or do we need a stock of finished goods? *Demand type* refers to where the production orders originate. It could be either from forecasts, from calculated requirements according to the company's safety stock policy, or due to customer orders [1, 2]. *Source of demand* indicates the origin of the sales order. Either it comes from a stock replenishment order (vendor managed inventory (VMI)) or an actual customer order [1]. *Volume/frequency* refers to the annual manufacturing volume per year and the number of times per year that products are manufactured. This variable ranges from a few large customer orders per year, to a large number of customer orders per year. Another alternative is that customers can place call-off orders that are based on the company's production and delivery schedules [1]. *Frequency of customer demand* is defined as the number of times within a defined time period where there is a demand for a specific product. *Unique* refers to only once within an observation period. *Block-wise or sporadic* means multiple times, but no recognizable regularity. *Regular* means that the demand can be calculated for each time period by using a certain formula. *Continuous* refers to a demand that is about the same in each observation period [2]. *Time distributed demand* refers to how detailed the calculated demand is. The demand can either be time distributed or just given as an annual figure [1]. *Demand characteristics* indicate whether the demand is independent or not [1]. Independent demand is demand for a finished product, while dependent demand is demand for component parts or subassemblies [14]. *Type of procurement ordering* say something about the way the company is procuring goods. Two possibilities are listed for this variable: order procurement or order releases from a delivery agreement. The first one refers to a situation where the company is simply ordering their calculated needs from a supplier, while the last one refers to an integrated solution where the company has agreed on a delivery agreement with their suppliers regarding regular deliveries [1]. *Inventory accuracy* represents the accuracy of the stock on hand data [1]. Inaccuracies in the stock data could be due to poor discipline regarding keeping the data updated or poorly designed systems.

Manufacturing process related variables
Manufacturing mix indicate, from a manufacturing perspective, whether the products are considered homogeneous or mixed [1]. Do the products require more or less the same production process, or are there differences? *Shop floor layout* is an important variable that indicate how the shop floor is organized [1-3]. There are many different way to categorize layout types, but in this framework the typology by Slack et al. [8] is used, which defines four types: *Fixed-position, functional, cell,* and *product layout*. *Type of production* refers to the average size of the production run and how frequently they are repeated [2, 3]. Lödding [3] differentiates between four types: *single unit production, small series, serial production,* and *mass production.* Table 1 states the differences between these four.

Table 1: Four types of production [3]

One-time production	Small series	Serial production	Mass production
Small production runs No repetition	Size of production run < 50 Number of repetitions < 12	Size of production run > 50 Number of repetitions < 24	Very large production runs Continuous production

Through-put time indicates the typical through-put time in the production, i.e. the time used by a product to go through the entire production [1]. This could range from hours all the way up to years. *Number of major operations* refers to the number of major operations in a typical production routing [1]. *Batch size* represents the typical manufacturing order quantity [1]. For ETO, MTO, and ATO companies, the batch size is usually equivalent to the customer order quantity. For MTS companies, the batch size can for instance be measured relatively to the number of weeks of demand the batch size cover. *Frequency of production order repetition* says something about, within a defined time period, how often a production order for the same product will be made [2]. *Fluctuations of capacity requirements* refer to how much the production capacity requirements vary. The capacity fluctuations are mainly due to fluctuations in customer demand, but usually not as strong as the demand oscillations [3]. *Planning points* indicate the number of manufacturing resources that can be regarded as one entity from a production and capacity planning point of view [4]. *Sequencing dependency* indicate whether the manufacturing set-up times are dependent on the manufacturing sequence [1]. This could for instance be that some products are produced with the same tooling, while other products require other types of tooling. *Set-up times* refer to the typical time that is required to prepare the necessary resource in order to perform the specific task [1, 4]. *Part flow* refers to

the method of transporting parts between workstations [3]. Four distinct types of part flow are outlined in the framework. *Bulk* refers to a situation where the entire batch is processed together. For a *lot-wise flow*, smaller parts of the batch, i.e. lots, are transported and processed together. *Overlapped flow* refers to the case where an already processed portion of a lot is transported to the next workstation in order to keep up the utilization. The last type are *one-piece-flow* which means that the part is transported to the next workstation as soon as it has been processed [3]. *Material flow complexity* says something about the complexity regarding the material flow at the shop floor. The complexity increases with the number of possible different possible routings in the production [3]. *Capacity flexibility* refers to which degree the company are able to adjust the capacity and how quickly they can do it [3]. *Load flexibility* refers to the possibility of adapting the load to the available capacity. This can for instance be done by shifting the start or end-date of an order, placing orders externally, or declining orders when capacities are fully booked [3].
It is obvious that some of these 30 variables are interrelated, and the framework aims to investigate some of these relations. Inspired by the product profiling concept by Hill [12], the production environment (ETO/MTO/ATO/MTS) was chosen as an “overarching” variable used to sort the values for the rest of the variables. The framework has been structured so that the different values correspond to what is considered typical for the production environment. This means that typical ETO characteristics have been placed to the left, MTS characteristics on the right, with a natural transition in between. By filling out the framework, one can obtain a profiling for the company.

5 Case Samples

The framework has been used to map the planning environment of five case companies. This includes a shipyard, a manufacturer of ship propulsion systems, a furniture manufacturer, a pipe manufacturer, and a manufacturer of underwater sensor systems. Because of the large differences regarding the product complexity and market requirements, it is expected that there also will be significant differences in the planning environments. By utilizing the proposed framework, it will be easier to concretize the actual differences.
Kleven is a shipyard that both produces new vessels as well as offering service, repair, and rebuilding of all types of vessels. Their products have a very complex structure, the production lead times are long, and there is a lot of coordination required in the production. *Brunvoll* produces thruster systems for ships. The products are mostly standard, but there are some adaptations to the thrusters depending on the customer requirements. These products have a highly complex structure, and they produce around 350 units a year. The low volume produced lead to a very uneven load on the machines, and large variations in throughput time. This again results in problems coordinating the production flow. *Ekornes* is a furniture producer that produces according to customer orders. They are offering mass customization through providing the customer with choices regarding e.g. the color of their furniture. A large part of their production is manual labor. They struggle with variable lead-time and therefore also with coordinating the production flow. *Pipelife* produces plastic pipe systems used for among other water, ventilation, and electrical purposes, which are standard products. Because of very strict required delivery times, they have to produce to stock. They have issues with calculating future demand, which lead to stock build-ups. In addition, the setup times in production are extensive, which means that they have to carefully balance batch size with responsiveness. *Kongsberg Maritime Subsea* develops and produces underwater acoustic sensor systems used in underwater mapping, underwater navigation and fishing. They are producing standard products with some room for customer specifications. Because of the P/D ratio, where the required delivery lead time is considerably lower than the production lead time, products are made to stock. Of the major challenges in the current planning and control are long throughput times and high WIP levels. These issues are a consequence of the high product complexity and the high material flow complexity in the job shop environment. Furthermore, it is a lack of suitable methods for planning and control that can handle the high product variety, especially related to controlling the material flow on the shop floor.
In order to test the integrated framework, the planning environments of the five case companies have been investigated. Each variable have been looked into and classified according to the classification scheme in the framework. The results from the case study are presented in table 2.

Table 2: Integrated framework for mapping the planning environment.
A: Kleven**, B:** Brunvoll**, C:** Ekornes**, D:** Pipelife, **E:** Kongsberg Maritime Subsea

Category	Variable	Values					Ref.
Product related	CODP placement	ETO **A, B**	MTO **B, C**	ATO	MTS **D, E**		[1, 2]
	Level of customization	Fully customer specific **A**	Some specifications are allowed **B, C, E**	None **D**			[1]
	Product variety	High **A, B, C, E**	Medium	Low **D**			[1, 3, 4]
	BOM complexity	More than 5 levels **A, E**	3-5 levels **B**	1-2 levels and several items **C**	1-2 levels and few items **D**		[1, 2, 4]
	Product data accuracy	Low **A, B**	Medium **A, B, C**	High **C, D, E**			[1]
	Level of process planning	None	Partial process planning **A, C, E**	Fully designed process **B, D**			[1]
Market related	P/D ratio	<1 **A, B, C**	1	>1 **D, E**			[1]
	Demand type	Customer order allocation **A, B, C**	Calculated requirements	Forecast **D, E**			[1, 2]
	Source of demand	Customer order **A, B, C, D, E**	Stock replenishment order **D, E**				[1]
	Volume / frequency	Few large customer orders per year **A, B**	Several customer orders with large quantities per year	Large number of customer orders with medium quantities per year **C, D, E**	Frequent call-offs based on delivery schedules		[1, 4]
	Frequency of customer demand	Unique **A, B**	Block-wise or sporadic **B, C, E**	Regular **C, D, E**	Steady (continuous)		[2]
	Time distributed demand	Time distributed **A, B, C, E**	Annual figure **D**				[1]
	Demand characteristics (*)	Dependent **B**	Independent **A, C, D, E**				[1]
	Type of procurement ordering (*)	Order by order procurement **A, B, C, D, E**	Order releases from a delivery agreement **C, D**				[1]
	Inventory accuracy (*)	Low	Medium **C**	High **A, B, D, E**			[1]
Manu-facturing process related	Manufacturing mix	Mixed products **A, C, E**	Homogenous products **B, D**				[1]
	Shop floor layout	Fixed-position **A, B**	Functional **C, E**	Cell **B**	Product **D**		[1-3, 8]
	Type of production	Single unit production **A, B, E**	Small series **B, E**	Serial production **C**	Mass production **D**		[2, 3]
	Through-put time	Years **A**	Months **A, B, E**	Weeks **B, C**	Days **C, D**	Hours **D**	[1]
	Number of major operations	High **A, B, E**	Medium **C**	Low **D**			[1]
	Batch size	Equal to customer order quantities **A, B, C**	Small, equal to one week of demand **E**	Medium, equal to a few weeks of demand **D**	Large, equal to a month's demand or more **D**		[1]

<table>
<tr><th>Category</th><th>Variable</th><th colspan="12">Values</th><th>Ref.</th></tr>
<tr><td rowspan="9"></td><td>Frequency of production order repetition</td><td colspan="4">Non-repetitive production
A</td><td colspan="4">Production with infrequent repetition
B</td><td colspan="4">Production with frequent repetition
C, D, E</td><td>[2]</td></tr>
<tr><td>Fluctuations of capacity req.</td><td colspan="4">High</td><td colspan="4">Medium
A, B, C, E</td><td colspan="4">Low
D</td><td>[3]</td></tr>
<tr><td>Planning points</td><td colspan="4">High
A</td><td colspan="4">Medium
B, C, E</td><td colspan="4">Low
D</td><td>[4]</td></tr>
<tr><td>Sequencing dependency</td><td colspan="3">None</td><td colspan="3">Low
C, E</td><td colspan="3">Medium
A, B</td><td colspan="3">High
D</td><td>[1]</td></tr>
<tr><td>Set-up times</td><td colspan="4">Low
C, E</td><td colspan="4">Medium
A, B</td><td colspan="4">High
D</td><td>[1, 4]</td></tr>
<tr><td>Part flow</td><td colspan="3">One-Piece-Flow
A, B</td><td colspan="3">Overlapped
E</td><td colspan="3">Lot-Wise
B, C, D</td><td colspan="3">Bulk (Batch)</td><td>[3]</td></tr>
<tr><td>Material flow complexity</td><td colspan="4">High
A, E</td><td colspan="4">Medium
B, C</td><td colspan="4">Low
D</td><td>[3]</td></tr>
<tr><td>Capacity flexibility</td><td colspan="4">High</td><td colspan="4">Medium
C</td><td colspan="4">Low
A, B, D, E</td><td>[3]</td></tr>
<tr><td>Load flexibility</td><td colspan="4">High
A</td><td colspan="4">Medium
B, C, E</td><td colspan="4">Low
D</td><td>[3]</td></tr>
<tr><td colspan="15">(*): Not dependent on production environment</td></tr>
</table>

6 Discussion

This study investigated and evaluated existing frameworks for identifying a manufacturing company's planning environment characteristics. An integrated framework based on a number of these different frameworks has been developed, consisting of 30 different variables. Because of interrelations between the variables, the framework is structured in a way that companies clearly should see a pattern, a so-called company profiling, when populating the framework depending on their type of production environment.

Even if the framework is extensive, it is not considered to be very complicated in terms of required user knowledge, but the user should know the company well and have a basic understanding of PPC terms. It can also be discussed whether it is necessary to include all of the variables. The variables included should say something about the planning environment that is not already covered by other variables. This has been the premise when choosing variables for this framework. However, the connections and relations between the different variables should be investigated further.

As mentioned earlier, many of the variables are interrelated. In chapter 4, it was mentioned that there are typical "ETO characteristics" and "MTS characteristics". To some degree, the case study confirmed this. Companies that produce complex, customized products see that many of their variables correspond to the values on the left side in table 2. On the other hand, companies that mass-produce standardized products will find that their variables mostly correspond to values on the right side in table 2. However, some of the variables are not considered to be dependent on the type of production environment. This includes *demand characteristics, type of procurement ordering,* and *inventory accuracy.* These variables will therefore stand out when classifying the companies, as they are not part of the previously mentioned pattern.

This framework may be used to do an initial screening of a manufacturing company and get an overview of their planning environment. It presents straightforward variables that can be used as a comprehensive checklist for analyzing manufacturing companies and their planning environment. The framework can be seen as a step towards establishing a common reference framework that can be used as a basis for future research in this field. It can for instance be a starting point to identify appropriate PPC methods for the particular environment. By using the framework to map different companies, it will be easy to compare them and identify similarities and differences. This way, it could also be used as a benchmarking tool to compare against, for instance, a company that is considered "best-in-class", and identify possible improvement areas.

In addition, similar to Hill's [12] product profiling concept, the integrated framework can be used to analyze the match between product and market characteristics and the manufacturing process characteristics. The framework identifies any mismatches between the product and market characteristics and the manufacturing process choices. The profiling makes it easy to identify which areas that should be looked into for better conformance between the different groups of characteristics [15].

There are typically four ways to address a mismatch in the profiling [15]: The first choice is to "live with it" and continue as before. The second choice is to alter the marketing strategy to ensure a better fit with the existing manufacturing process. The third choice is to adjust and change the manufacturing process so that it to a larger degree matches the competitive priorities of the company. The fourth choice is to go for a combination of the second and third choice.

7 Conclusion and Future Work

Through the literature findings, it became clear that there is a need for an integrated framework for evaluating planning environments in order to get a comprehensive understanding of the important variables, supported by among others Jonsson and Mattsson [1]. The integrated framework presented here comprehends more variables than any of the other frameworks investigated, and will therefore highlight a larger portion of the relevant characteristics of a planning environment. Through testing the framework on five manufacturing companies, the initial results show that the framework is working well regarding mapping the planning environments.
However, in order to ensure the validity of the framework, more extensive case studies should be conducted. In addition, it should be investigated whether it is beneficial to make the variables and their respective values more precise. This can give a more detailed mapping of planning environment. Lastly, additional effort should be put into exploring the relationships and interactions between the variables. It might be that there is some redundancy between the variables, which means that some of them might be unnecessary.

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