The Lack of "Clean" Communication

The influence of implementing an Interorganizational system on expected workload forecasting within a Circular, dyadic business-to-business relationship

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ABSTRACT

Over the past decade, an increasing amount of supply chains started using Interorganizational systems in order to increase information distribution to improve the cooperation within the chain. This thesis is aimed at giving directions towards a properly operating IOS within a circular, dyadic business-to-business relationship, which informs the buyer of the expected workload and employee occupation, based on mathematical models using supplier data. This research indicates that an IOS could drastically improve forecasting accuracy, namely in this case with 17.1%. Implementing an IOS would give access to hourly forecasting possibilities instead of daily based forecasting, which will increase business performance.

Keywords: IOS, Circular, Supply Chain, Mathematical modelling, Forecasting.

INTRODUCTION

Interorganizational Systems (IOS) have become increasingly important for companies over the past decades, partially due to the increasing importance of good Supply Chain Management (Wang et al. 2014a). Especially in healthcare, IOS should always display up-to-date data to prevent mistakes from happening, since mistakes in these environments can have disastrous consequences (Cohn, J., 2017). Combining this with the healthcare trend of reducing costs while improving quality of services (Goudswaard, A. P., 2006; Tlahig, Jebali, Bouchriha, & Ladet, 2013), optimizing IOS's within hospital networks should become one of the top priorities.

Problem Situation

Within the past decade, multiple medical centres have decided to outsource their central sterilization activities to commercial providers of these services (Goudswaard, A. P., 2006; Tlahig et al., 2013). After doing research the UMCG (Universitair Medisch Centrum Groningen) decided to replace the CSA (Centrale Sterilisatie Afdeling) in a new location outside of the hospital, named SteriNoord, a so called Shared Sterile Centre (SSC). The prime driving forces of this decision were increasing quality of performance, cost-efficiency and improving the professional collaboration between both parties (Goudswaard, A. P., 2006).

As to be expected, the toughness of performing as a successful organization, just after the relocation, was too much to realize. According to prior research, the current delivery reliability of SteriNoord fluctuates around 78%. Within an area where mistakes and delays can cause real problems, this percentage is far too low. According to prior research at SteriNoord, one of the causes of this problem is the lack of an integrated IOS, which among others, hinders the possibility to make proper forecasts of expected workload, creates data inconsistency and unjustified staff planning, and negatively influences the possibility of interfirm communication between SteriNoord and the UMCG (De Waal, C. J. C., 2017).

A well-known example from literature that confirms this problem is faced in many situations is the bullwhip effect, which appears in supply chains where a small order variability at the customer level amplifies the orders for upstream players, such as the wholesalers, distributors and eventually the factory, as the order moves (upstream) along a supply chain, due to the lack of interfirm communication (Paik, S. K., Bagchi, P. K., 2007). In order to mitigate the bullwhip effect, supply chain managers need to share actual demand information and coordinate production and distribution activities with their partners (Paik & Bagchi, 2007).

Research Design

The current relationship between SteriNoord and the UMCG can be classified as a circular, dyadic, business to business relationship. According to Guide & van Wassenhove (2000), one of the keys to success within such a business relation is the ability to forecast and control the timing, quantity, and quality of product returns by using an IOS. However, SteriNoord and the UMCG both use different IOS's, which disables them to reach this success factor. This is strange, since within a circular, dyadic B2B relationship, good communication is top-priority (Guide & Van Wassenhove, 2000). Just for clarification: multiple key constructs which are used throughout this thesis are defined in table 1 on the following page.

Within this thesis the focus will be placed on the possibility to improve workload expectations within a circular, dyadic, business to business situation by implementing an integrated IOS. Hence the main research question of this thesis is: *How can an IOS effectively confer expected workload information within a circular, dyadic business to business relationship?* By answering this question, a solution will be provided for any company in a similar situation how their workload forecasting and thus indirectly their delivery reliability can be improved whilst implementing an IOS. In order to be able to give answer to the main research question, it will be divided in two sub-questions.

The first sub-question is: *To which extent can the workload of the supplier be predicted by looking at data of the buyer?* This will be measured by making a mathematical model to guide workload-forecasting for the supplier. This mathematical model provides a basic framework for any company in a similar situation to make workload-forecasting easier. The second sub-question is: For this, a combination of literature study will be used together with in-depth interviews to measure which factors are required for a successful IOS. How both sub-questions will be answered will be explained further on in the methodology.

By creating a mathematical model to guide companies in calculating the possible improvement of workload- and personnel occupation forecasting by implementing an IOS, this thesis will add significantly to existing literature. By providing a mathematical measurement tool for comparing different ways of forecasting, this thesis fills the current literature gap. Next to this, the existing literature about IOS mostly concerns regular business to business relationships or supply chains. It could be of interest to focus on a circular, dyadic B2B relationship in the field of healthcare, since these situations are unique and complex.

The remainder of this paper is arranged as follows: Firstly, the theoretical framework will be discussed. Secondly, the conceptual model will be presented and discussed, and hypotheses will be stated. Thirdly, the methodology will be presented, wherein will be explained which methods were used to answer the research questions. Fourthly, the results of the research will be presented and later on discussed and a conclusion will be drawn wherein the sub- and main questions will be answered and discussed. Finally, limitations of this research and directions for future research are presented.

Constructs	Definitions
Interorganizational System (IOS)	An automated information system shared by two or more companies (Konsynski, 1985).
Dyadic business-to-business (B2B) relationship	A business relationship between two firms.
Circular relationship	Supplier delivers to the buyer and the buyer delivers to the supplier, creating a circular relationship.
Shared Sterile Centre (SSC)	Result-Responsible Unit, established by one or more (joint venture) medical centres in a region providing sterile medical devices to health care providers in that region, based on an agreement and at a settlement price (Goudswaard, A. P., 2006).

Table 1: Definitions

THEORETICAL FRAMEWORK

Within this thesis the focus will be on IOS in circular, dyadic B2B relationships. Compared to regular B2B relationships, this relationship is very complex, due to the need of information visibility and consistency. There are many supply chains where information may not be shared due to constraints such as compatibility of information systems, information quality, trust and confidentiality (Ali et al. 2017). However, circular relationships thrive on information sharing and full disclosure (Guide & Van Wassenhove, 2000), which makes it even more interesting to research what impact the implementation of an IOS may have within this particular situation of SteriNoord.

Another point of difference between a circular and regular B2B relationship is that within a circular, dyadic relationship, the supplier delivers her products or services to the buyer, whilst the buyer also delivers his products or services to the supplier. In literature this is also known as the forward and reverse supply chains (Östlin, J., Sundin, E., Björkman, M., 2008). Generally, the forward chain concerns the flow of physical products from the manufacturer to the customer, while the reverse chain describes the flow of used physical products from the customer, then acting as supplier, to the remanufacturer. Hence both companies are suppliers and buyers at the same time. Regular B2B relationships mostly have forwards logistics, which represents a downstream flow, from factory to consumer (Östlin et al., 2008). The reverse supply chain makes the sharing of information even more important to ensure ease and control over the supply chain. Next to this, it will enable both companies to effectively coordinate the supply chain as well (Östlin et al., 2008).

Important Aspects of Interorganizational System

Recently, companies started recognizing the importance of Interorganizational Systems (IOS) and begun to use IOS to integrate their processes with those of their supply-chain partners to improve their supply-chain operations (Wang et al., 2014). A very simple IOS definition would be "an automated information system shared by two or more companies” (Konsynski, 1985). An IOS is built around information technology, i.e., around computer and communications technology that facilitates the creation, storage, transformation, and transmission of information (Johnston & Vitale 1988).

Within the situation of SteriNoord and the UMCG, there is no overlap between the different systems, which makes the communication and sharing of information between both companies difficult. Instead, both parties have a private, internally distributed information system. This is especially inefficient since there can be spoken of a circular, dyadic B2B relationship where information sharing is one of the top priorities in order to be successful (Guide & Van Wassenhove, 2000). An IOS differs from an internal, distributed information system by allowing information to be sent across organizational boundaries (Johnston & Vitale 1988). Not having an IOS in a complex situation does hinder the productivity, efficiency and quality of production processes (De Waal, C. J. C., 2017). According to Williamson (2011), trust and commitment can be damaged by not having an IOS.

An IOS manages to facilitate the distribution, visibility and consistency of information. Johnston and Vitale (1988) define information distribution as *the distribution of information throughout a supply chain, across organizational boundaries*. As information distribution increases, the efficiency of an IOS may increase as well. Information visibility facilitates *the real-time coordination of interfirm processes* (Rai, A., Patnayakuni, R., Seth, N., 2016). Prior studies have recognized that IOS integration can provide information visibility to mitigate the bullwhip effect (Wang et al., 2014). In recent years, there has been a greater tendency to use IT systems to make inventory, transportation and pricing decisions based on greater visibility of information. Sharing of information proves to be the backbone for various formal coordination initiatives such as Collaborative Planning, Forecasting and Replenishment (CPFR), Efficient Consumer Response (ECR) and Forecast Information Sharing (FIS) (Ali et al. 2017). Information consistency has been defined in prior studies as *the degree to which common data definitions and consistency in stored data have been established across a focal firm's supply chain* (Rai et al., 2016).

The usefulness of an IOS is dependent on the ease of use and training/coaching. The easier a system is to use, the more efficient personnel can operate with it. Throughout literature ease of use is defined as *the degree to which a person believes that using a particular system would be free of effort* (Davis, F., 1989). As personnel is able to operate efficiently and easily with the system, more input can be gathered and generated within a smaller timespan. In order to prepare their workers to do their job as desired, organizations provides training as to optimize their employee's potential (Elnaga, A., & Imran, A., 2013). Training/coaching thus refers to *programs that provide workers with information, new skills, or professional development opportunities.* Effectively training employees and leveraging and managing the "knowledge assets" of an organization can be critical to the success of that organization (Schmonsees, R. J., 1999).

Conceptual Model

In order to give a visual representation of the expected cause-effect relationships in this research, a conceptual model was constructed. As was stated earlier, forecasting is difficult for SteriNoord, due to the absence of an IOS (De Waal, C. J. C., 2017). This also is one of the causes for the low delivery reliability of SteriNoord. Focussing on improving workload & required staff forecasting, "accuracy of forecasting" is used as main variable within the conceptual model. Within this thesis, accuracy of forecasting is defined as *the correctness of predicting what has to be produced for the incoming time span*. It is positively influenced by the variable "Mathematical Modelling". A mathematical model can be defined as a quantitative representation, or idealization, of a real problem (Albright, S. C., Winston, W. L., 2012). Within the current situation, mathematical modelling may offer new insights in forecasting workload for suppliers, enabling the supplier to react in time to certain demand fluctuations. This might enable the supplier to plan and reschedule any requirements.

The extent to which the supplier can predict workload expectations by using forecasting modelling may positively influence workload forecasting of the supplier by making it easier to do. Workload, what is technically called: the offered-load, depends on the arrival process and the service times that each arrival (customer) requires (Aldor-Noiman, S., Feigin, P. D., Mandelbaum, A., 2009). Within this research, the role of an IOS on forecasting will be researched. Hence, "Interorganizational System" is a positive moderator of the relation between mathematical modelling and accuracy of forecasting, as it is expected to have a positive influence on the accuracy of forecasting within a circular, dyadic B2B relationship. The following conceptual model was constructed:

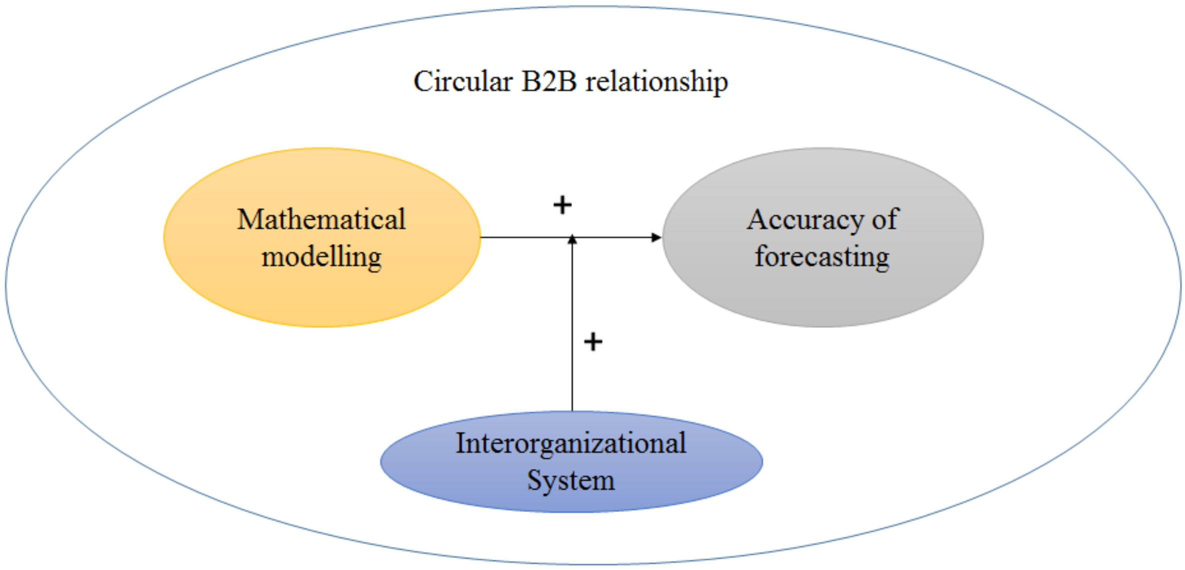


Figure 1: Conceptual Model

HYPOTHESIS

After creating the conceptual model, it is possible to construct multiple hypothesis according to the relations between the variables depicted in the model. This results in the following hypothesis:

H1: Mathematical modelling has a positive effect on the accuracy of forecasting within a circular, dyadic B2B relationship.

H2: An Interorganizational System has a moderating positive effect on the effect of mathematical modelling on the accuracy of forecasting within a circular, dyadic B2B relationship.

The hypothesis will be researched and afterwards confirmed or rejected.

METHODOLOGY

In order to answer the first sub-question, two mathematical models were constructed. The first mathematical model is created to forecast the expectable workload with historical data of the seller. This is a method many companies use to predict their demand, if there is no IOS in use. There is no communication between companies about expected production, which represents the current situation of SteriNoord. Model two is created to use present data flow, representing the situation with an IOS.

Mathematical Model 1

For this first model, the method of moving averages was used (Albright et al, 2012). The moving averages method uses the average of the observations from the past few periods and uses it as a forecast for the next period. In order to implement the moving average method, a timespan has to be chosen. The span is the number of terms in each moving average (Albright et al, 2012). For example: if the data is daily, a span of five days (Monday to Friday) can be used to forecast the value for the next day, which is the average of the previous five days' values (Albright et al, 2012). This can continue constantly, creating a "moving average". In case of Y_t being the actual forecast of period t, and F_t being the forecast for the next period, N for the span chosen for the calculation, the formula for moving average is the following:

$$F_t = \frac{\sum_{t=1}^{N} Y_{t-N}}{N}$$

The larger the span, the smoother the forecast will be (Albright et al, 2012). This is due to the fact that extreme observations in that case have less effect on the averages, resulting in a smoother forecast. Since for SteriNoord extreme observations are of importance, a relatively small span will be used, namely, a span of five days.

Mathematical Model 2

The second mathematical model was created to forecast the expectable workload with future data to receive from the buyer. This was done by using the modelling technique of Otto and Day (2007). In their book techniques are presented that can be readily applied to model phenomena in many different disciplines. This model was constructed by following their 7-steps method, which can be seen in the appendix. Step one until four will be discussed in the research design, since those steps are a guide to set up a good analysis of the situation and create a working model, or formula. Step five until seven will be discussed in later sections due to that those steps are aimed on testing the model with data about the variables used in the model.

In step one the problem situation needs to be described and questions have to be formulated so that you can describe the model in a question. The problem was described in the problem statement and formulating these research questions was done in the research framework.

In step two, the ingredients of the model need to be determined (variables, parameters and boundaries). As we are speaking of a specific situation, variables and parameters will be used that are not to be used for any regular B2B situation. The output of the model will be given as the required amount of employees for the different dayparts fitting to the forecasted workload. In order to calculate the expectable workload for SteriNoord, the variables that are used are:

- The amount of operations of the UMCG;
- The amount of operation sets used per operation.

These variables are connected, as every operation requires at least one operation set. Dependent on the kind of operation, the main operation set can be added with additional required operating tools from another set. Parameters of the model are the following:

- The amount of SteriNoord employees required per amount of sets;
- The capacity of the SteriNoord washing machines;
- The capacity of the SteriNoord autoclaves;
- The capacity of the nets for the washing machines/autoclaves.

As variables and parameters have constraints, table 2 has been constructed to grant a clear overview of limitations for the model. As employees of SteriNoord are able to process an average of 5 sets per hour, it was necessary to convert the other parameters to # sets per hour as

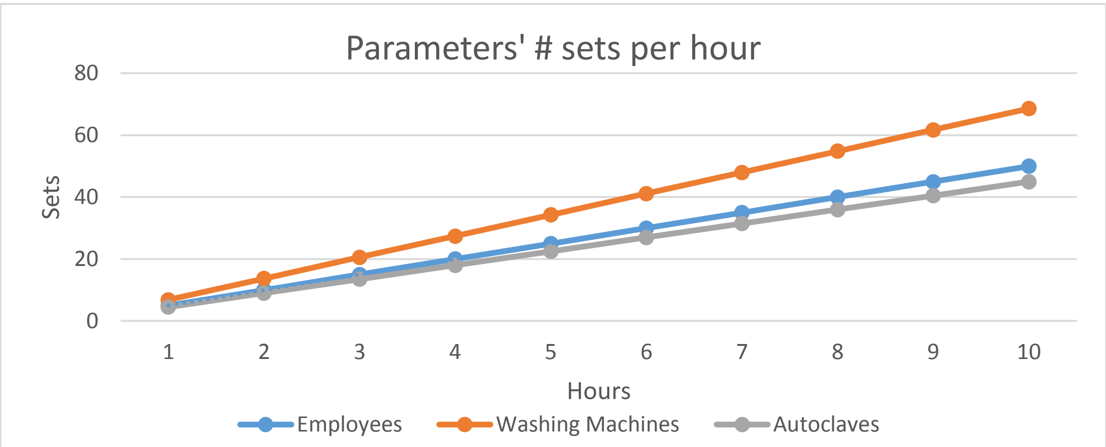


Figure 2: Parameters' # sets per hour

well. By doing this, the following linear graph was created (figure 2). As can be seen in the

Variables/Parameters	***Constraints***
Every variable/parameter	Never < 0
Washing machines	Availability ≤ 10
Autoclave	Availability ≤ 6
# of sets per employee per 60 minutes	Capacity 3 ≤ X ≤ 7
Nets in washing machine	Capacity ≤ 12
Nets in autoclave	Capacity ≤ 9
# of sets in a net	Capacity ≤ 1
Duration of washing machine	Duration ≥ 75 minutes
Drying time after washing machine	Duration ≥ 30 minutes
Duration of autoclave	Duration ≥ 120 minutes

graph, the autoclaves are the bottleneck of the process, with an average of 4.5 sets per hour.

Table 2: Constraints of variables/parameters

However, there is room to place four more autoclaves, which would increase the capacity of the autoclaves in total to 90 sets in two hours. This would alleviate the bottleneck.

In step 3 a qualitative description of the system is made. This is done by drawing a life-cycle diagram which is to be seen in figure 3. A life-cycle diagram keeps track of the various events occurring during a single time step, along with their order of occurrence (Otto, S. P., Day, T., 2007). However, the usefulness of life-cycle diagrams becomes less when there can be spoken of multiple variables, since there is only one event per life cycle. Since this is the case at SteriNoord, it is advised to make a flow diagram to gain a better image of the interconnections between the different variables.

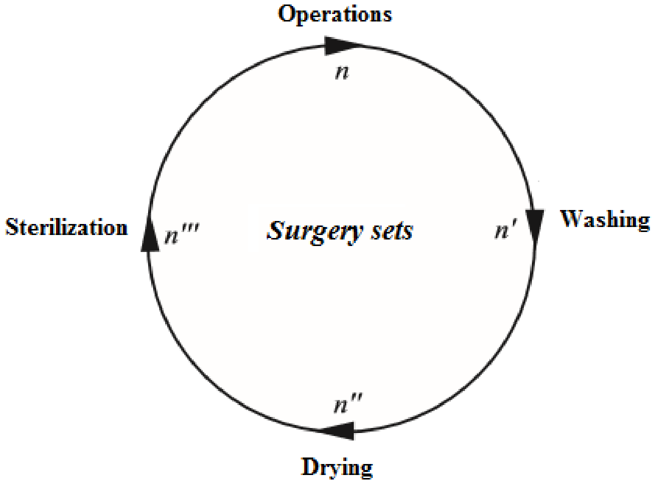
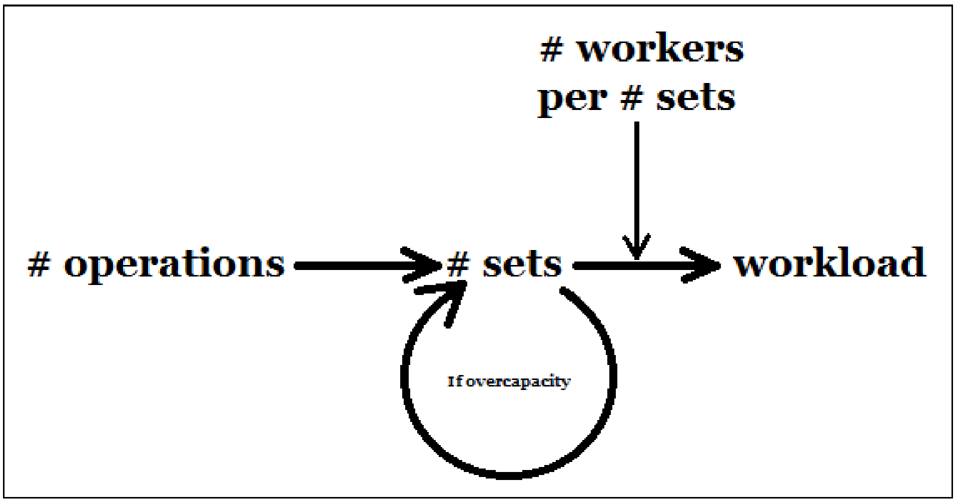


Figure 3: Life-Cycle Diagram

Hence a flow diagram was constructed (Figure 4), which illustrates the interconnections among the variables and provides a schematic picture of how each variable affects its own dynamics as well as the dynamics of the other variables (Otto, S. P., Day, T., 2007). The circles in the model represent one variable. The amount of operations determine a specific amount of operation sets. SteriNoord can only handle up to a certain capacity of surgery sets per hour. Hence the loop is created, so that if there can be spoken of overcapacity, the remaining sets which cannot be cleaned immediately, will have to wait and be cleaned in the next round. By forecasting the expectable workload, the required amount of workers will be



calculated.

Figure 4: Flow Diagram

In step 4 a quantitative description of the system is made. Considering the variables, parameters and the flow diagram that was set up to visualize the dynamics of the different variables, a formula can be constructed. In order to forecast the amount of employees required on site, the amount of sets used per operation, the capacity of the system and the employee parameter (α) need to be taken into consideration. Within table 3 all variables are described and connected to a certain character.

Character	*Description*
$E_{(t)}$	Employees required at time *t*
$S_{(t)}$	Sets at time *t*
S_{max}	Maximum capacity of # sets
α	# employees per # sets
O	Overcapacity

Table 3: Definitions of characters forecasting formula

Putting all the variables into an equation, the following formula is the result:

$$E_{(t)} = \left(S_{(t)} + O_{(t)}\right)\alpha$$

$$O_{(t)} = S_{(t-1)} - S_{max}$$

$$Taking\ into\ consideration\ that:$$

$$O_{(t)} \geq 0$$

$$O_{(t+5)} = 0$$

This formula will calculate how many employees are required at time *t*, considering the maximum capacity of the company, allowing overcapacity to sit up till 5 hours before it has to be processed. This is bound to the situation of SteriNoord, as there is a contractual deal with the UMCG that all dirty sets have to be returned sterile within twelve hours. The five hours were chosen as a maximum delay to ensure the contractual claim is being achieved. For any other company, this boundary is dependent on their contractual claims or arrangements.

Error Calculation

In order to compare the forecasts of both models to calculate whether an IOS is worth the implementation, the Root Mean Square Error (RMSE) and the Mean Absolute Percentage Error (MAPE) can be calculated. These errors indicate how far off the forecast (F*t*) is from the actual figures (Y*t*) (Albright et al, 2012). The formulas for the RMSE and MAPE are the following:

$$\text{RMSE} = \sqrt{\frac{\sum_{t=1}^{N} |E_t^2|}{N}} \qquad \text{MAPE} = \frac{\sum_{T=1}^{N} |\frac{E_t}{Y_t}|}{N}$$

By scoring the first formula, working with historical data, the difference in quality of forecasting can be compared with the quality of forecasting with present data, which is estimated to be 98%. Precisely 100% is practically impossible, since even in an IOS, data flaws can come up due to human inattention, and some emergency orders might not be communicated via the official way due to the requirement of focus on speed and fast acting.

ANALYSIS

Step 5: Analyse the equations/ Step 6: Checks and balances. According to the surgery data of the UMCG covering the period of 28-02-2017 until 31-03-2017, a distribution diagram can be constructed (figure 5) to gain a clear picture of which times the most chirurgical interventions are finished. Calculating this data into the average amount of sets that are used daily per timeslot, figure 6 can be constructed. As this result is gained by taking averages of an entire month, this is not really representative for the daily amount and its variability. Hence the data will have to be processed to daily figures, so that the moving average method can process the data into forecasts.

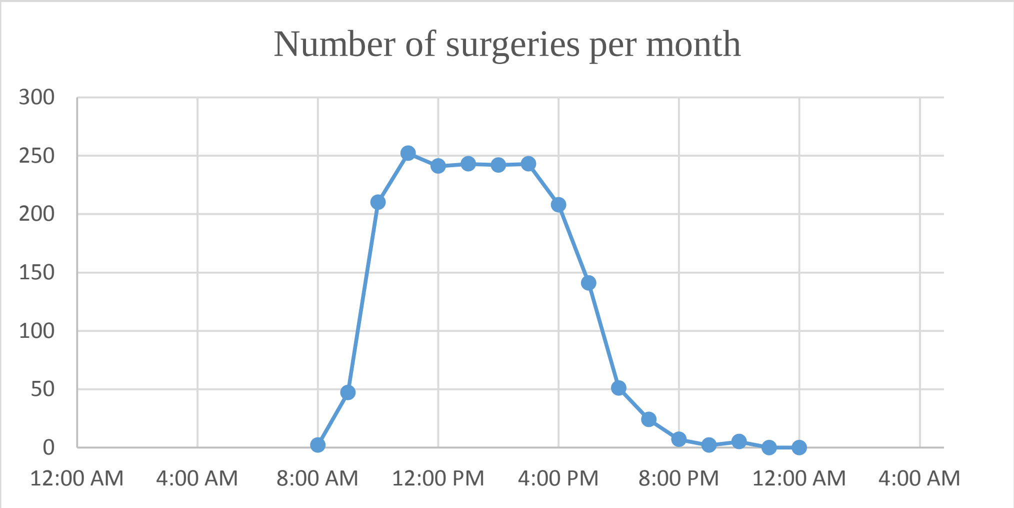


Figure 5: Number of surgeries per month at time t

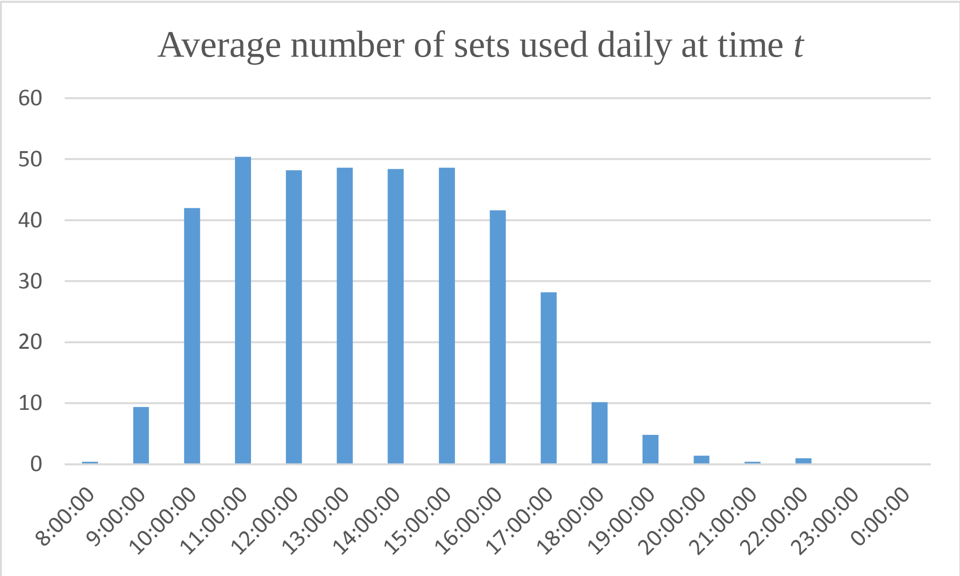


Figure 6: Average number of sets used daily at time t

According to the company director of SteriNoord, planning personnel is hard, due to the fluctuating demand of the UMCG. Throughout time, personnel occupation was estimated per day, as there are days with standard more surgeries, for example Mondays and Thursdays. Constructing a plot of the personnel occupation of the month March (Figure 7), it is clear that the amount of personnel nearly does not change over time, in the contrary against the fluctuating demand of the UMCG. This results in over-occupancy and undercutting.

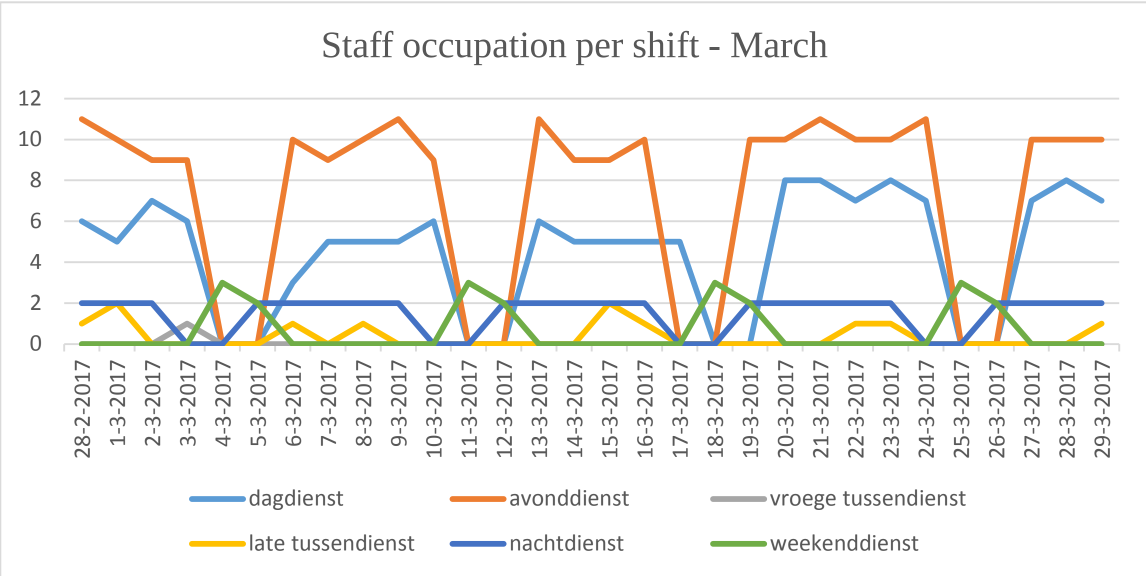


Figure 7: Staff occupation per shift - March

After processing the data to daily figures and running a variance and standard deviation check on the data, it appears that there is a big variance in the demand of the UMCG to SteriNoord (figure 8). This does not only result in indistinctness about what to expect from the UMCG, it also results in indistinctness about how much personnel is required for the different timeslots of SteriNoord (figure 9). It appears that implementing an IOS for the communication between the UMCG and SteriNoord may be a decisive decision for the success of this cooperation. Both figures are to be found on the following page.

This problematic situation of having no clue what to expect due to the high variance in demand represents the current situation of SteriNoord. This means working with the historical data forecasting function, in this case using the moving averages method, does not meet the required forecasting for functioning on a highly professional level. However, forecasting based on present data, would allow SteriNoord to act on the high level of demand-variance of the UMCG, enabling to accurately forecast the required amount of employees at time *t*. Not only will this allow the information visibility and collaboration between both companies to increase, also costs of over-occupancy, undercutting and delays could be prevented.

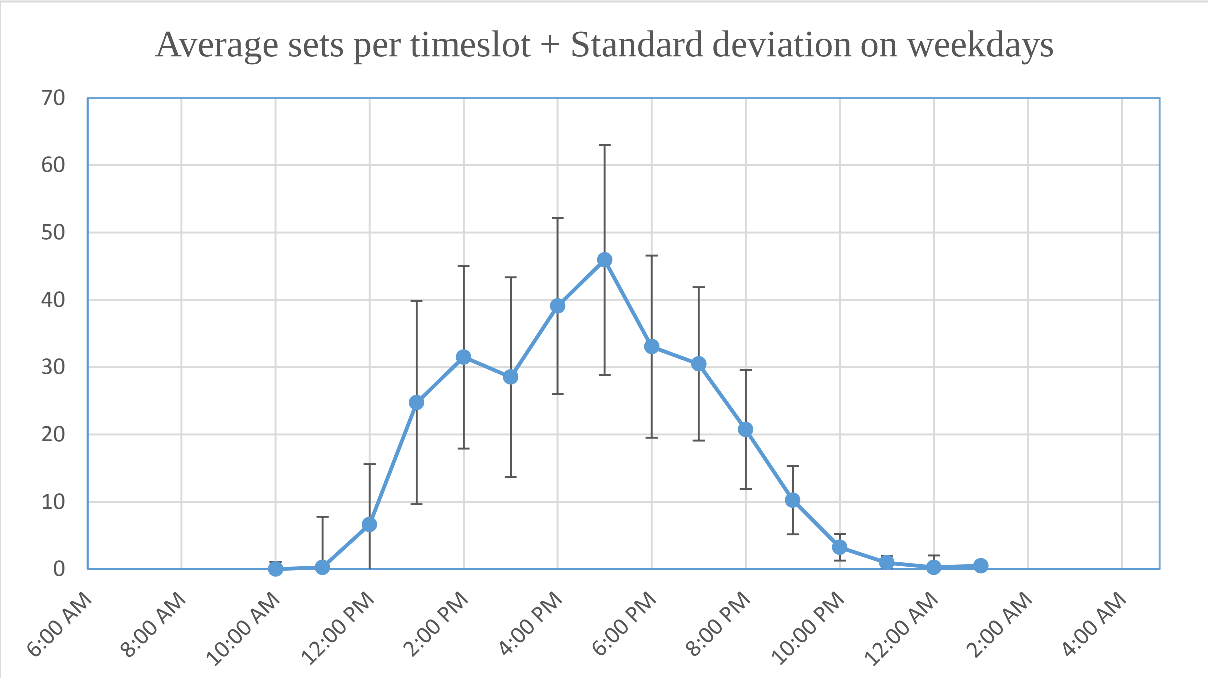


Figure 8: Average sets per timeslot + Standard deviation on weekdays

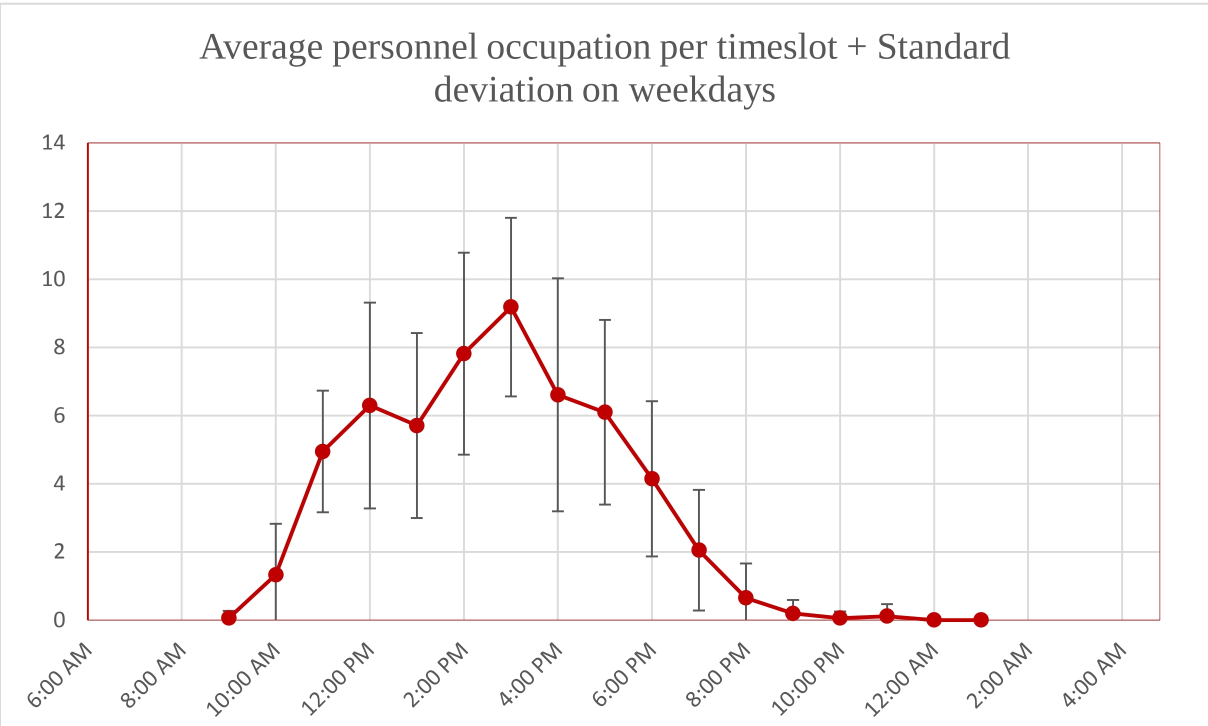


Figure 9: Average personnel occupation per timeslot + Standard deviation on weekdays

After analysing and processing the data, the mathematical models can be used to calculate the error percentage of the forecasting of both situations with the following formulas discussed earlier:

$$\text{RMSE} = \sqrt{\frac{\sum_{t=1}^{N} |E_t^2|}{N}} \qquad \text{MAPE} = \frac{\sum_{T=1}^{N} |\frac{E_t}{Y_t}|}{N}$$

With an average error calculated of 30 sets per day (RMSE) and a mean average percentage of 17.1% (MAPE), it seems obvious that there can be spoken of a serious problem. Due to the forecasts based on historical data, the accuracy of the forecasting lacks greatly. There is too much variation in the demand of the UMCG which makes the outcome of the formulas unreliable. However, without the variability, this would not be the case. Hence the historical forecasting method could prove its use for other situations. Next to this, the error rate is calculated on a daily basis. With an IOS, predictions on specific parts of the day can be made, which is very hard to do with forecasting with historical data. This will increase the error rate even further.

On top of this, after calculating the required employee occupation with the present data formula presented, it is possible to compare this outcome to the actual occupation of employees. The result is rather shocking. Approximately 83% of the time there can be spoken of over-occupancy, most often (61%) even of 6 employees or more (figure 10). The remaining 17 percent represents the moments of perfect occupation or undercutting, most often seen when the first large loads from the UMCG come in (figure 11).

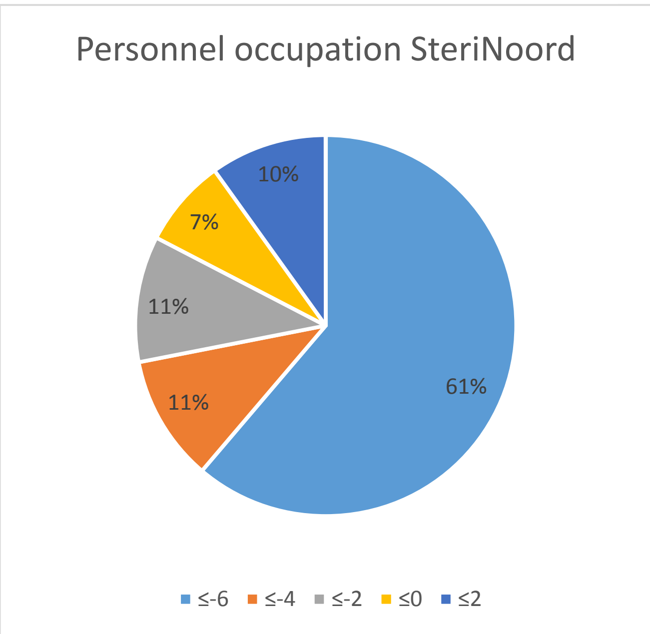


Figure 10: Employee occupation SteriNoord

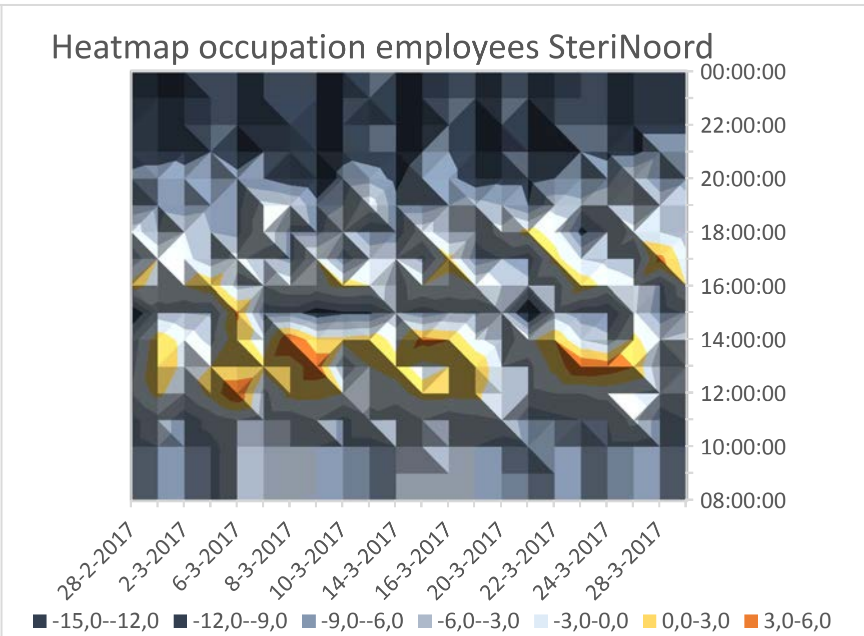


Figure 11: Heatmap occupation employees SteriNoord

DISCUSSION

The analysis shows that the model does give us a sharp representation of the possible improvement by implementing an IOS. Not only does the information distribution, visibility and consistency increase by implementing an IOS, also the company's performance will increase significantly. Hereby, both hypotheses are supported. Mathematical modelling has a positive effect on the accuracy of forecasting within a circular, dyadic B2B relationship and an Interorganizational System did strengthen the moderating positive effect of mathematical modelling on the accuracy of forecasting within a circular, dyadic B2B relationship.

The Root Mean Square Error and the Mean Average Percentage Error show that forecasting with historical data does not provide a clean forecast as is required, with an average error calculated of 30 sets per day and a percentage of 17.1%. However, this forecasting formula is basic. Advanced historical data forecasting formulas allow you to forecast with the eye on trend and seasonality, which might increase the accuracy of the forecasts (Albright et al, 2012).
On the other hand, since SteriNoord does not use this kind of forecasting formulas, it would be unrepresentative to use those methods for these circular supply chains.

Next to this, the potential improvement of employee occupation forecasting by implementing an IOS is enormous. As was displayed in the analysis, 83% of the time, there are too much employees at work compared to the workload received from the UMCG. Of course, there are other tasks to do next to packing the washing machines and autoclaves, but this is a very large percentage, displaying the potential improvements and cost-savings of implementing an IOS. Visibility of information could significantly increase the performance of SteriNoord.

Implications for Research & Practice

As the variation plot of the amount of sets shows, implementing an IOS would be very useful (Figure 8). However, this result might turn out limited for other situations. Since this complex, circular B2B relationship can fully benefit from the open information flow an IOS could supply, there are no disadvantages from sharing information, since there is no other competition (Goudswaard, A.P., 2017). For regular supply chains, where competition is one of the major threat factors influencing the business relationships between companies (Porter, M. E., 2001), sharing sensitive information by holding on to open information flow might be very risky. Hence companies might not want to share all the information about their capacities and state of technology in order to maintain their status within the market and/or their competitive advantages. Next to this, the constraints presented in this model are not very common. It should be obvious that everyone trying to use this model should carefully determine their own constraints according to their company's situation. No situation is exactly the same. This could also mean that *n* variables have to be added in order to make the formula suit the company's situation.

CONCLUSION & RECOMMENDATIONS

Within this thesis a mathematical model is presented to easily calculate what the implementation of an IOS could bring with it according to forecasting workload and personnel occupation. The model does allow any company to compare their current situation to a situation with an IOS, forecasting according to present data. According to recent literature, an IOS increases information distribution, visibility and consistency, which in return allows the company to improve its performance (Johnston & Vitale 1988; Rai et al., 2016).

Hereby we reached step 7: Relate the results back to the research question. Answering the first sub-question: "*To which extent can the workload of the supplier be predicted by looking at data of the buyer?*" By processing the data and working with the mathematical model, it was possible to test the historical data forecasting formula against the present data forecasting formula. Forecasting with historical data normally could give a pretty accurate forecast. However, within such a complex and variable situation as healthcare may be, the forecasts cannot give an accurate expectation working with historical data. This research shows that the average error rate of forecasting per day in this situation is 17.1%, which is a very high number, causing delay, resulting in extra costs and disabling SteriNoord to operate to their full potential. Next to this, processing the data through the formula shows that in the current situation 83% of the time the employee occupation is too high, resulting in a large unnecessary amount of labour costs. Forecasting with present data, featuring an IOS, will enable companies to work with accurate forecasts and properly distribute the flow of information, possibly increasing the company's performance significantly.

Answering the second sub-question: "*With which requirements should an IOS comply within a circular, dyadic business to business relationship?*" From a theoretical perspective the conclusion can be drawn that within a circular, dyadic B2B relationship, an IOS should comply with the same requirements within a normal B2B situation. However, according to literature, the visibility/traceability of information requires additional emphasis (Guercini, S., Runfola, A., 2009), due to the fact that circular, dyadic business relations thrive on sharing as much information as possible (Guide & Van Wassenhove, 2000). Increased information visibility enables the level of traceability to increase, resulting in more organisational control and market power (Guercini, S., Runfola, A., 2009). This way, both the customer and supplier can analyse the process in an optimal way, enabling visibility for possible improvements and status of the required or expected processes (Guercini, S., Runfola, A., 2009).

Combining the answers of the first sub-questions in order to give answer on the main research question of this thesis: *"How can an IOS effectively confer expected workload information within a circular, dyadic business to business relationship?"* a conclusion can be made that by creating proper information distribution, visibility and consistency, mathematical models should be able to process present data into accurate forecasting, even up to hourly forecasts to fine-tune employee occupation. The results of the research show that within a circular, dyadic B2B relationship, forecasting based on historical data does not suit the complex situation, as a high level of information visibility is required. Next to this, accurate and timely forecasts are required to ensure quality and efficiency of the production process, enabling the company to perform on its highest level.

Directions for Future Research

"It is easy to think of the completed model as the end of the process, however, a completed model is really a starting point", as Albright and Winston (2012) stated. It is important to see the model as a starting point and dive into the possible improvements of the implementation of an IOS, also taking a close look at the downsides as costs, implementation time, delay and the acceptance within the organisation. Concerning the requirements of IOS within a circular, dyadic business-to-business relationship, this thesis does only theoretically treat requirements from regular business-to-business relationships. The theory discussed in this thesis should be tested by conducting qualitative research in order to discover whether the factors treated are recognized and/or required.

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APPENDIX

Seven Steps to Modelling a (Biological) Problem – Otto & Day, 2007.

Step 1: Formulate the question:

What do you want to know? Describe the model in the form of a question. Boil the question down! Start with the simplest, (biologically) reasonable description of the problem.

Step 2: Determine the basic ingredients:

Define the variables in the model. Describe any constraints on the variables. Describe any interactions between variables. Decide whether you will treat time as discrete or continuous. Choose a time scale (i.e., decide what a time step equals in discrete time and specify whether rates will be measured per second, minute, day, year, generation, etc.). Define the parameters in the model. Describe any constraints on the parameters.

Step 3: Qualitatively describe the (biological) system:

Draw a life-cycle diagram (see Figure 2.2) for discrete-time models involving multiple events per time unit. Draw a flow diagram to describe changes to the variables over time. For models with many possible events, construct a table listing the outcome of every event.

Step 4: Quantitatively describe the (biological) system:

Using the diagrams and tables as a guide, write down the equations. Perform checks. Are the constraints on the variables still met as time passes? Make sure that the units of the right-hand side equal those on the left-hand side. Think about whether results from the model can address the question.

Step 5: Analyse the equations:

Start by using the equations to simulate and graph the changes to the system over time. Choose and perform appropriate analyses. Make sure that the analyses can address the problem.

Step 6: Checks and balances:

Check the results against data or any known special cases. Determine how general the results are. Consider alternatives to the simplest model. Extend or simplify the model, as appropriate, and repeat steps 2–5.

Step 7: Relate the results back to the question:

Do the results answer the (biological) question? Are the results counterintuitive? Why? Interpret the results verbally, and describe conceptually any new insights into the (biological) process. Describe potential experiments.